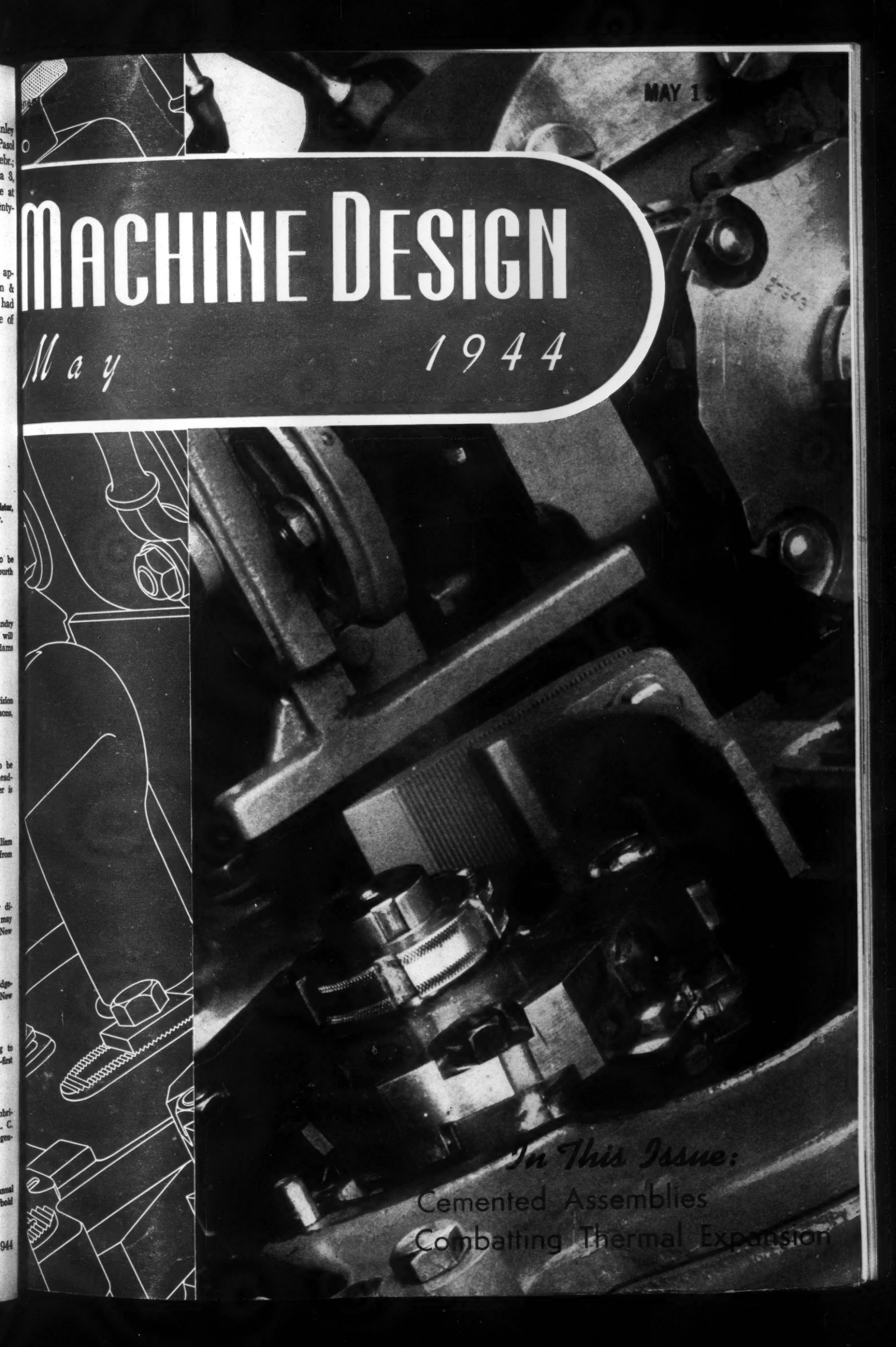
MAY 1
MACHINE DESIGN
May 1944
In This Issue:
Cemented Assemblies
Combatting Thermal Expansion

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MACHINE DESIGN

THE PROFESSIONAL JOURNAL OF CHIEF ENGINEERS AND DESIGNERS

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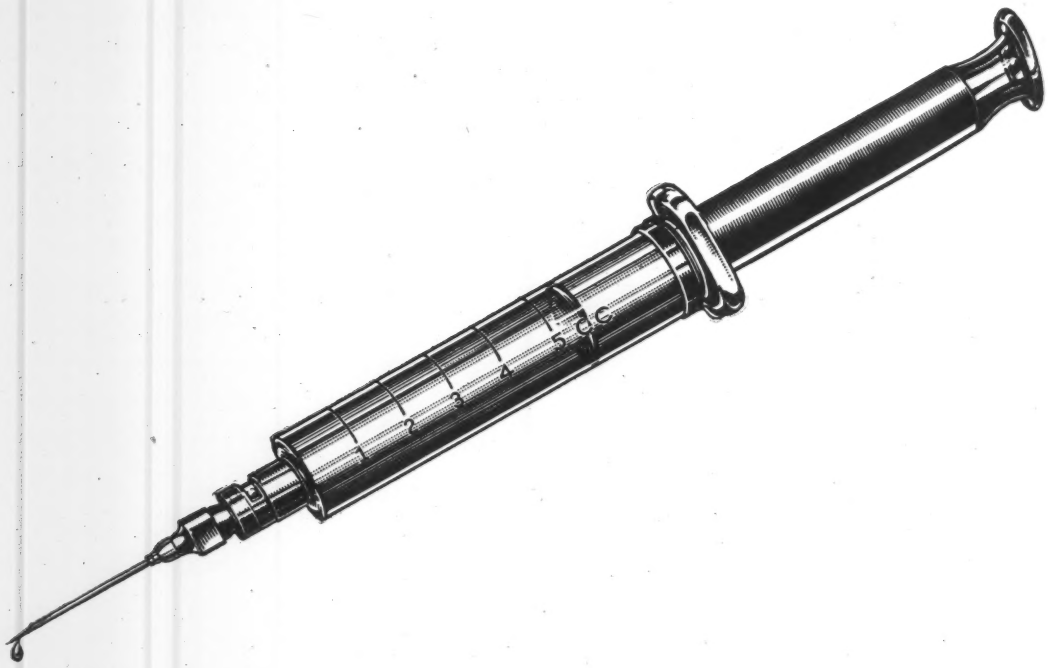

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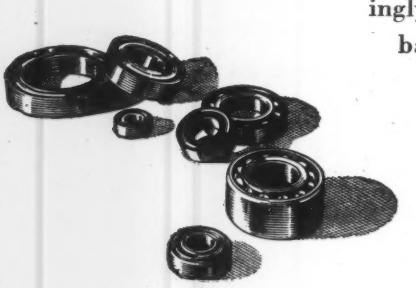

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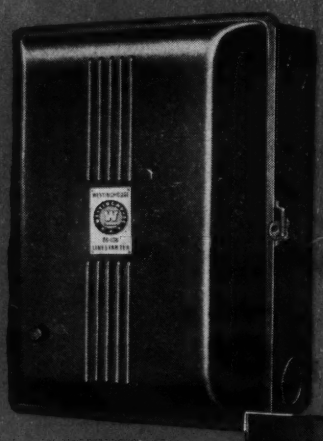
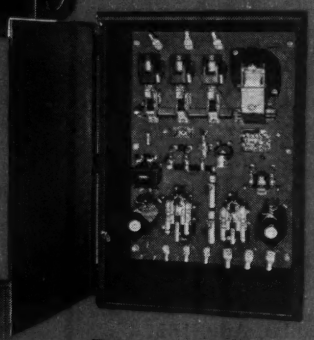


Across-the-line A-C Magnetic Starter for Squirrel-cage Motors.



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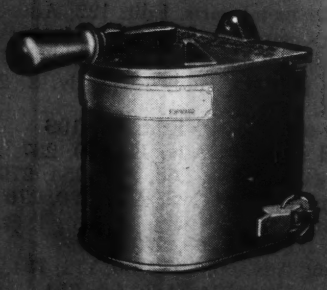


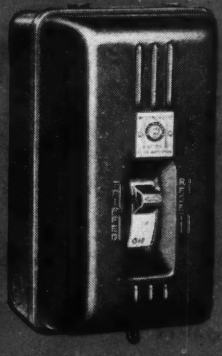
Reversing Drum Switches for Across-the-line Starting.

Type H Sentinel Breaker for Fractional Hp Motor Starting.

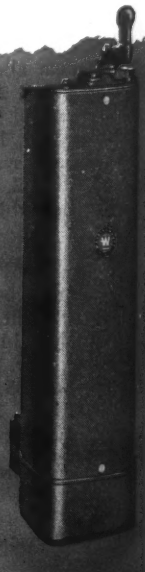
Manual Multi-speed Drum Controllers.

"De-ion" Motor Watchman Reversing and Two-speed Manual Starters.

Manual Multi-speed Drum Controllers.



Across-the-line "De-ion" Manual Motor Starter.



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Motor Control

This issue at a glance

Cemented Assemblies Used on Fighting Aircraft . . . .

. . . . are saving time, parts and money. Also, they've plenty of muscle. Tests on recent assemblies showed higher strength than riveted joints in shear and impact, along with improved rigidity and greater fatigue resistance. Commencing on Page 79, John Delmonte surveys the field of adhesives and offers pertinent data on where and how to use them.

Choosing the Right Variable-Speed Drive . . . .

. . . . is often a headache. With so many types available, differing in characteristics, which to use? Fingertip facts can help. You'll find them—pertaining to electrical "changeable-speed" drives—in Colin Carmichael's article on Page 85.

Hydraulic Power, Electrically Controlled . . . .

. . . . is being used with outstanding success in the design of all types of production machines. Page 91 initiates a significant discussion on the methods used to achieve operation sequence in a semiautomatic shell lathe.

Demand Is for Better Strength-Weight Ratios . . . .

. . . . in machines of the future. Thus it is well to recognize the increasing importance of strain-rosette analysis in design studies of stress and strain, particularly where complex structures are involved. In his article beginning on Page 95, J. H. Meier presents a simple graphical method for determining strain-gage constants without the tedious tests and calculations heretofore required.

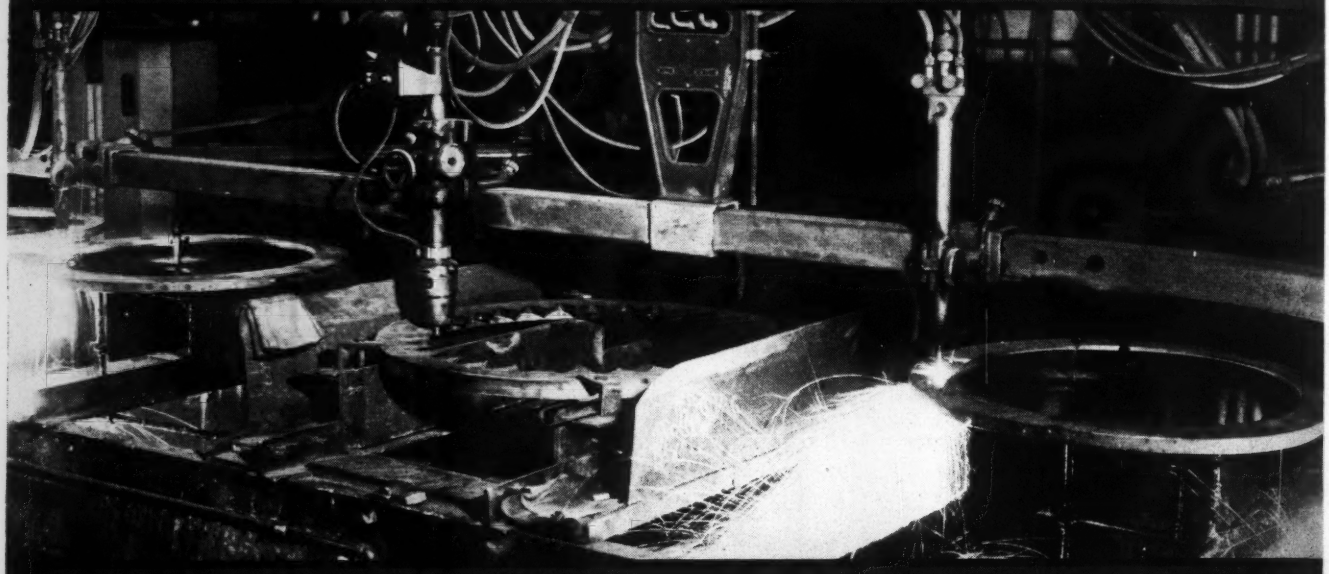
Need for Standard Hydraulic Symbols . . . .

. . . . becomes more and more acute. While key manufacturers have their own symbols, the general design field lacks a common language of hydraulics—is forced to improvise. See Page 97 for Bob Elberty's timely discussion and presentation of suggested standards.

There Are Lots of Patents . . . .

. . . . that don't amount to a row of peas. Others—few in number—are outstanding engineering accomplishments, representative of the latest in modern design. Particularly significant to the mechanical engineer are the recently granted patents discussed on Page 132.

Special Equipment, Experience and Quantity Production



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6. **Safe assembly in combination with bronze or brass parts.**
7. **Produced in all standard weaves and meshes.**

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Acceptance testing of 20-millimeter shell employs a device originating from attempts to find an automatic method of rejecting bad coins and making change in bottled-drink vending machines. Even the smallest defects are detected by dropping a shell on an anvil of the instrument which measures the frequency, amplitude and duration of the sound wave. A green signal light indicates if the shell is acceptable.

Raising the 30,000-ton U.S.S. Oklahoma, sunk by the Japs at Pearl Harbor, involved ingenuity and precise control on 21 winches to prevent breaking the ship. Huge timber A-frames mounted along the bilge keel distributed the stresses and provided the necessary turning movement through cables, reeved through compound pulleys to the winches on shore. G.E. variable-voltage drives were utilized for the task together with the necessary control devices.

Technical committee on metal powders and metal-powder parts has been organized by the A.S.T.M. to undertake the formulation of specifications and methods of tests for these materials. Technical representatives of leading producers and consumers are serving on the committee.

Over sixty minutes of speech may be recorded on .004-inch wire on a sound recorder developed particularly for use in observation planes. The spool containing the wire is no larger than a doughnut and the entire recorder weighs about 9 pounds. Recording is magnetic and may be "wiped off" without affecting the quality of the wire for further use.

Proper contrast in engineering drawings can be measured by a newly developed instrument to determine if they will produce satisfactory prints. Developed at the Glenn L. Martin Co. for training draftsmen, the instrument — called a Legimeter — compares intensity of pencil lines on the drawing being produced with a standard sample. If the drawing shows weak it may be "heavied" on the spot before sending it to the blueprint room, thus saving valuable time and rejects that otherwise would result.

Where inertia of springs in fast-moving mechanisms is critical, helical springs wound from tubular material have been found advantageous. Applications where high natural frequencies are needed include valve springs and gun recoil springs.

Cemented carbide parts too large to be sintered in available furnaces—as well as special, thin-walled parts which distort when processed in the regular way—may be produced by a "hot-press" method. Developed by Carboloy, the procedure employs electrical resistance heating to obtain the necessary sintering temperature. Molds in which parts are pressed and sintered are of a graphite-base composition.

Vacant spaces in the atoms of nickel are responsible for its resistance to corrosion, according to Dr. Uhlig of General Electric's research laboratory. Character of stainless steel is not due to the formation of oxide film on the surface as formerly supposed but rather to the electronic arrangement in the atoms. The same is true for monel and molybdenum-nickel alloys. Findings such as these may prove valuable in determining effective ways of overcoming corrosion and conserving vast quantities of valuable metals now being lost.

Production of direct-current motors reached an all-time high in February. Production was $16,816,000 compared to $12,731,000 in the same month of 1943.

Special air ducts for heatnig and ventilating aircraft, made from an asbestos product by U. S. Rubber, conserve aluminum and other metals. Made of fabric, asbestos and a coating of synthetic resin the new product makes possible the lightening of material used by more than 10 per cent and obviates intricate metal processing formerly required. Suitable for hot or cold air, the duct material is pliable and easily makes the bends required.

MACHINE DESIGN

Cemented Assemblies—Their Place in Design

By John Delmonte
Technical Director
Plastics Industries Technical Institute

RECENT developments in resin adhesives have prompted machine designers to consider cemented assemblies in lieu of riveted or welded construction. While there are some proved applications worthy of note, it is too early to evaluate the ultimate importance and relationship of cemented assemblies to the entire field of machine construction. However, it is recognized that when stresses arising in the assembly of machine components are distributed over the entire surface areas making contact, rather than at concentrated points of loading, such as rivets, spot welds, bolts and screws, an improved structure results. From a practical point of view this ideal condition has not yet been attained for many metal parts, though the ultimate is fairly close in the cementing of certain

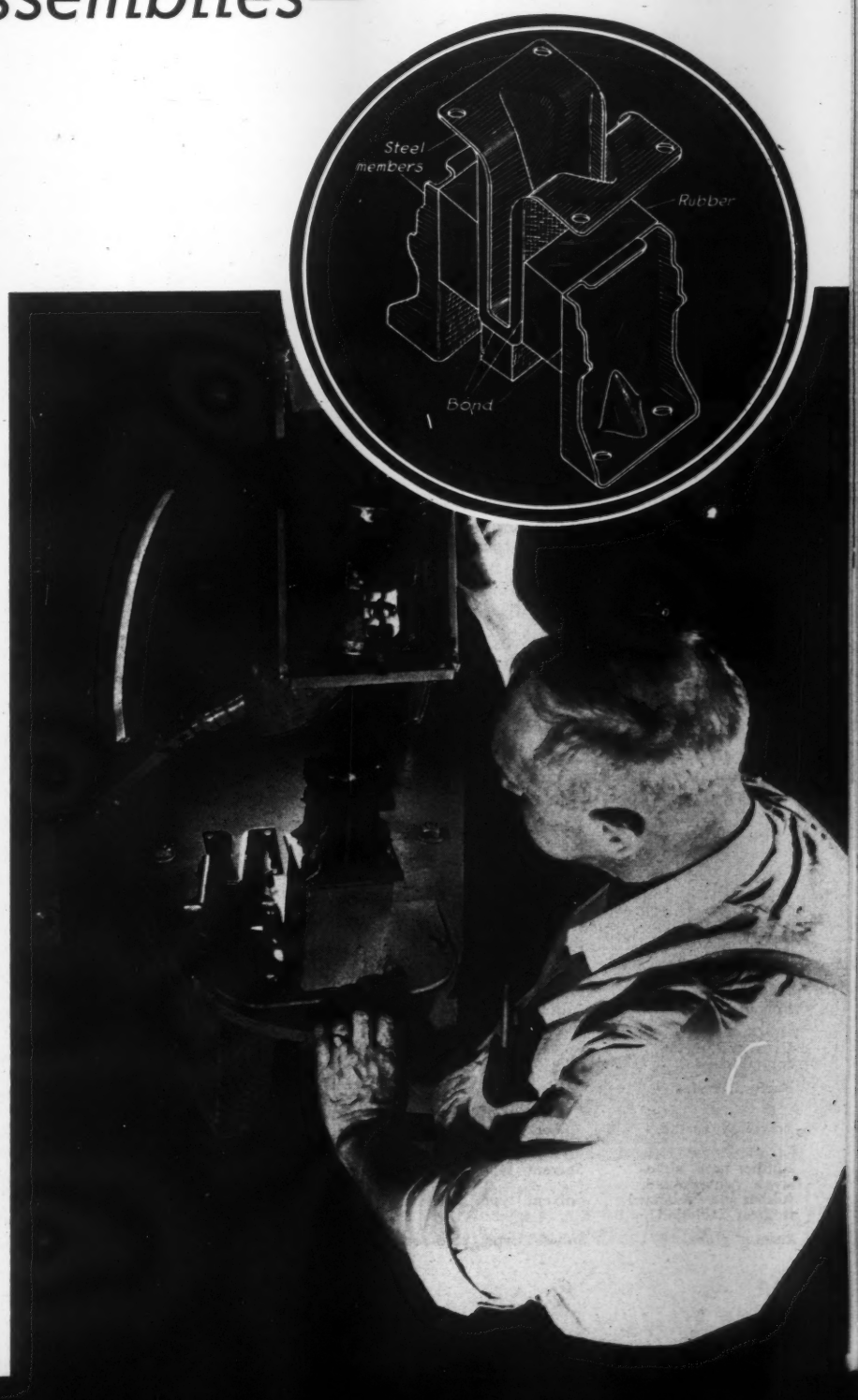

Fig. 1—An example of the high strength now being achieved in cemented joints. In these units, "Cycleweld" adhesive effects a sturdy rubber-to-metal bond

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RECENT developments in resin adhesives have prompted machine designers to consider cemented assemblies in lieu of riveted or welded construction. While there are some proved applications worthy of note, it is too early to evaluate the ultimate importance and relationship of cemented assemblies to the entire field of machine construction. However, it is recognized that when stresses arising in the assembly of machine components are distributed over the entire surface areas making contact, rather than at concentrated points of loading, such as rivets, spot welds, bolts and screws, an improved structure results. From a practical point of view this ideal condition has not yet been attained for many metal parts, though the ultimate is fairly close in the cementing of certain

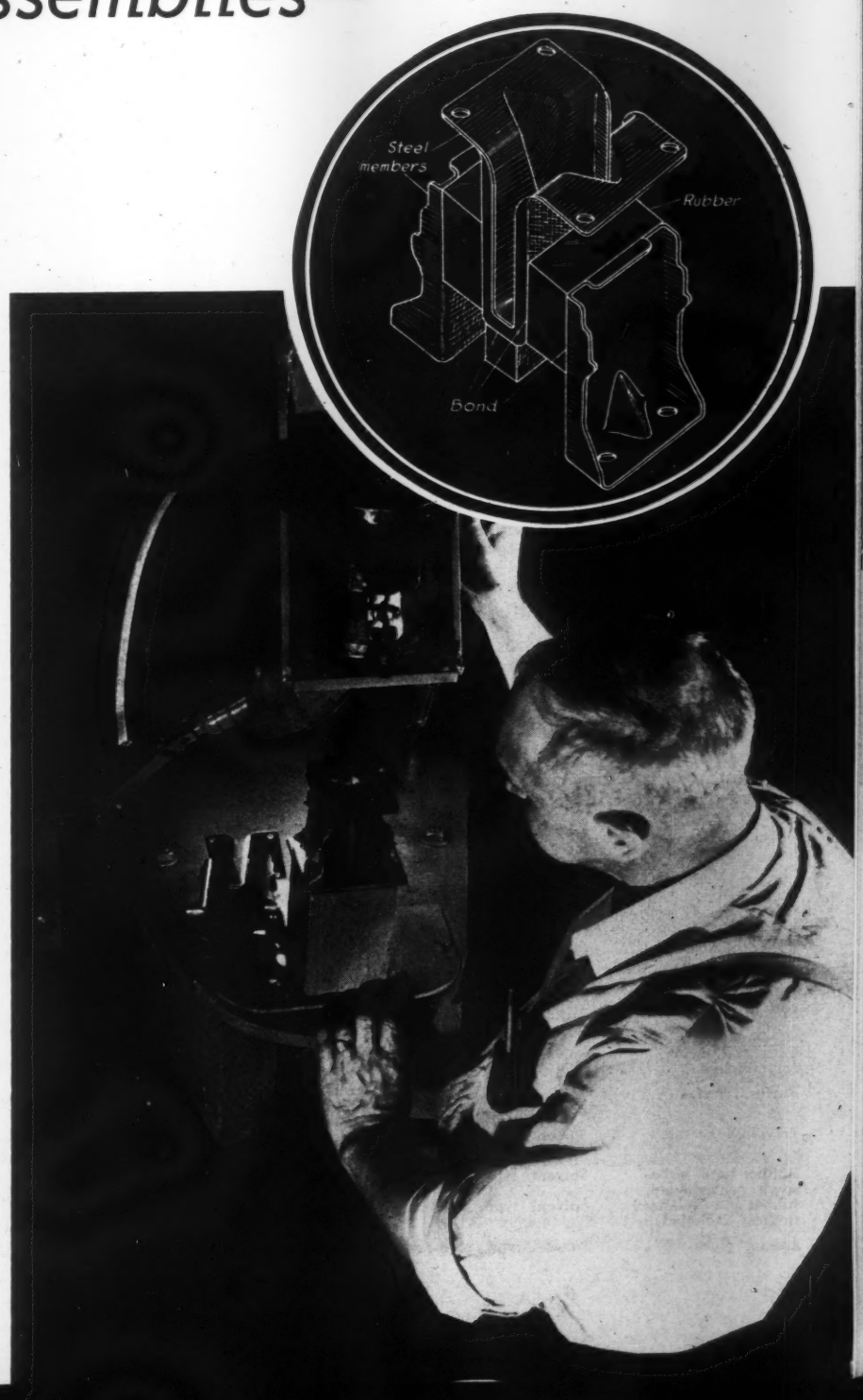


Fig. 1—An example of the high strength now being achieved in cemented joints. In these units, "Cycleweld" adhesive effects a sturdy rubber-to-metal bond

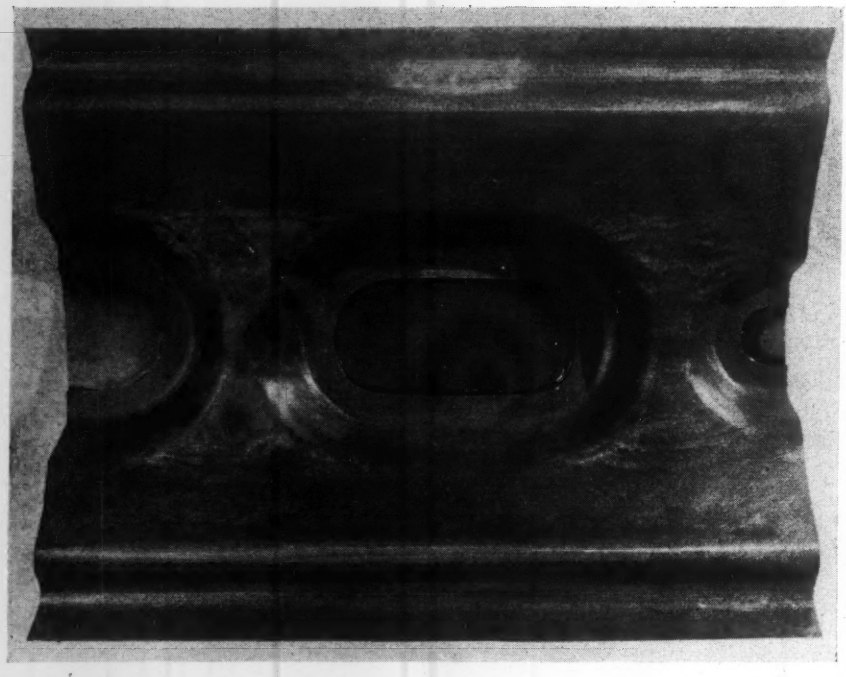


Fig. 2—Typical modern cemented assembly is this experimental door section of laminated phenolic for use on fighter plane. Resin-type adhesive was used

plastics, wood and rubber products.

In this article, analyses of the characteristics and limitations of current adhesives will be offered, along with suggestions for the proper specification of adhesives in design of machines.

The most common types of adhesives are a rubber-like material and a plastic material dissolved in a solvent. Partial evaporation of the solvent leaves the coating tacky, permitting adherence upon contact with many surfaces. In general, adhesives may be classified in one of several categories:

1. Temperature at Which Adhesives Set

(a) Cold or Room-Temperature Setting. May be applied effectively at room temperatures.

(b) Hot Setting. Require heat to set firmly. Most good metal adhesives fall within this category.

2. Origin of Adhesive

(a) Natural Resin Adhesives. Animal glues, protein material, cassava flour, etc., are various sources of adhesive materials.

(b) Synthetic Resin Adhesives. Urea, phenolic, melamine, polyvinyl acetate, and furfural resins are prominent in this category.

3. Weathering Characteristics

(a) Interior-Type Adhesives. Certain resin adhesives with poor resistance to moisture and weathering effects, such as casein, are classified as interior-type adhesives by the plywood industry.

(b) Exterior-Type Adhesives. Other resin adhesives possessing good weather resistance and low moisture absorption are classified as exterior-type adhesives.

4. Solvent Characteristics

(a) Solvent-Type Adhesives. Furnished or applied in solution form as with water, alcohol, or some appropriate solvent.

(b) Nonsolvent-Type Adhesives. Do not require any volatile material for their application. Certain liquid furane resins and phenolic resins fall into this classification. They generally require use of catalyst to accelerate cure.

There is no one adhesive which is particularly outstanding for all types of materials such as rubber, wood, plastics, or metals. Generally the selection of the adhesive depends upon the material being bonded. Until recently, when the material "Cycleweld" was developed, there were no adequate metal adhesives. Various assemblies have been completed with the aid of this rubber-like, solvent type, hot-setting adhesive. Typical of such assemblies is the one shown under test in *Fig.* 1. Considerable success is reported for various aircraft assemblies of stressed parts, such as tails, ailerons, etc.

Saves Parts and Weight—Cuts Costs

Applications of "Cycleweld" have been thoroughly tested and approved for aircraft parts, permanently bonding metals, woods and plastics to each other. They have withstood all types of vibration tests. In the design of a wing flap, for instance, the assembly of ribs, stringers, and stiffeners with this material eliminated 900 rivets, cut costs by 30 to 35 per cent and produced a lighter and stronger flap.

Two distinct types of "Cycleweld" cement now are being produced. One is used to bond all materials, except rubber, while the other will bond most materials to the various rubbers. Curing temperatures of 200 to 300 de-

Characteristics of Adhesives

Type of Adhesive	Classification	Where Used	Outstanding Properties	Typical Tradenames
Phenol-formaldehyde	Solvent type and dry film. Mainly hot-setting	Plywood manufacturing	Good weather and moisture resistance	Bakelite, Durez Cascophen, Tego
Phenol-formaldehyde	Liquid, hot-setting, nonsolvent type	Cementing of phenolics	Hard, strong glue with good weather resistance	Catalin C-200CZ
Urea and melamine-formaldehyde	Solvent type, hot and cold-setting	Bonding of wood assemblies	Ease of application and handling	Weldwood, Plaskon, Melmac
Furfural resins	Nonsolvent, cold-setting liquid type	Bonding of plastic, wood and rubber products	Low water absorption. Has chemical affinity for surfaces being bonded	Resin X
Polyvinyl acetate	Solvent type, hot-sealing	Adhesive for wood, plastic and metal products	Good general-purpose adhesive for interior use	Vinylseal, Cordo
Rubber-base adhesives (chlorinated rubber and cyclicized rubbers included)	Solvent type, cold-setting	Rubber and plastic products	Some types will create a 100% rubber failure	Vulcalock, Ty-ply Cycleweld
	Solvent type, hot-setting	Metal, wood and rubber parts	Excellent results in metal; aluminum seal	
Animal glues	Solvent type, cold-setting	Wood and paper products	General-purpose; for interior use	

grees Fahr. are used and in assembling parts, firm, uniform pressures are applied with suitable hydraulic or spring-loaded presses to obtain optimum results. From a design viewpoint, best production is realized when as much cementing as possible is accomplished in one pressing operation. Also of interest as metal adhesives are certain high-temperature setting types such as "Cordo 350" and "Bostick cements" which show excellent properties.

In the cementing of plastic materials, particularly good results have been obtained with the furfural resin adhesives developed by the writer. Containing no volatile matter, these adhesives have been designed to be quick-setting at low or room temperatures. They are the first developed which will insure a 100 per cent failure in the laminated phenolic plastic being bonded. Most types of synthetic rubbers, the new CR and MR resins, and most

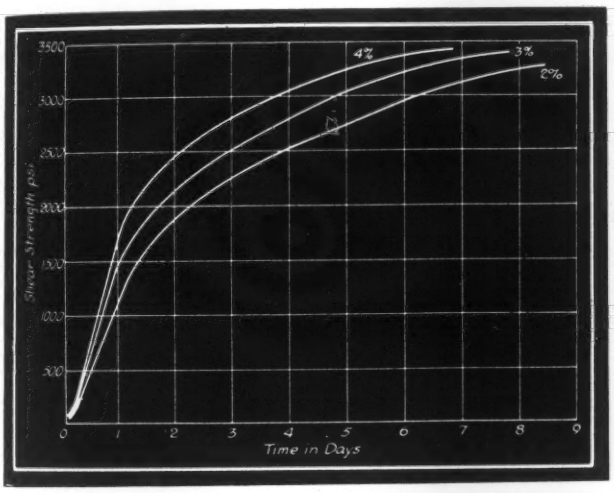


Fig. 3—Curves show effect of curing time on joint strength of two laminated phenolic sheets bonded with furfural resin adhesive having different percentages of catalyst Z-1A. Pressure: Zero. Cure temperature: 85 degrees Fahr.

thermoplastics and thermosettings can be bonded by these materials. In the bonding of rubber, the rubber will fail before the glue line. In one production application a facing of synthetic rubber was required on a molded phenolic valve member and an adequate bond was produced with Resin X cement. In another application, Neoprene sealing strips were successfully cemented to transparent acrylic sheets.

In *Fig.* 2 is illustrated a section of an experimental door of laminated phenolic for one of our fighter airplanes, bonded with the aid of Resin X adhesive. As would be expected from a nonsolvent-type adhesive, glue line thickness is not critical and, consequently, neither is pressure in assembly. This means that in the design of machine parts perfect contact of surfaces to be cemented is not necessary and the adhesive may be used to fill the voids.

Typical performance characteristics of this cement are shown in *Figs.* 3, 4, 5, and 6. The tests were performed on laminated phenolics, with contact pressure, under the curing conditions indicated. Availability of this cement has extended greatly the design scope of formed laminated phenolic parts now being employed extensively in aircraft, such as ejection chutes, ammunition boxes, tabs, etc. Water absorption of furfural resins, about .05 per cent in 24 hours, is lower than that of the phenolics.

Phenolic, urea, and melamine-formaldehyde resin adhesives are already enjoying widespread application as bonding agents for wood products. They have been developed for hot-setting and cold-setting procedures. Hot-bonded phenolics have proved especially valuable in exterior grades of plywood and in the molding of plywood by rubber-bag methods.

For general-purpose requirements of secondary bonding, urea-formaldehyde and melamine-formaldehyde resin adhesives have been excellent. These are being used extensively, for example, in the production of wing tips for one of our attack planes, and in lightweight, reinforced seats for paratroopers. To the machine designer, the wide-scale availability of strong, dependable wood adhesives will encourage greater adoption of these materials in various design problems. In most instances a 100 per cent wood failure can be anticipated before glue failure, this giving an indication of the strength of the assembly.

High-Frequency Heating May Be Used

The designer will find also that phenolic, urea, and melamine adhesives have been prepared in various forms permitting, when necessary, rapid assemblies by high-frequency heating, or longer assembly times with the use of low or room temperatures. Particularly effective adhesives of the latter classification have been prepared from resorcinol—formaldehyde resins which are related chemically to the phenol-formaldehyde types. With respect to the acid or alkaline catalyzed resins which set at low temperatures, it is imperative for the designer to make sure the pH conditions are not going to be detrimental to the parts being bonded.

In the design of machine parts to be cemented together, some care must be exercised in the cleanliness and preparation of surfaces which are to make contact. Metal parts should be wiped free of oils and greases with some solvent such as benzene or xylene. Generally the same is true of plastic parts undergoing bonding. In addition, better results usually are achieved when the surfaces are roughened before cementing to improve the mechanical

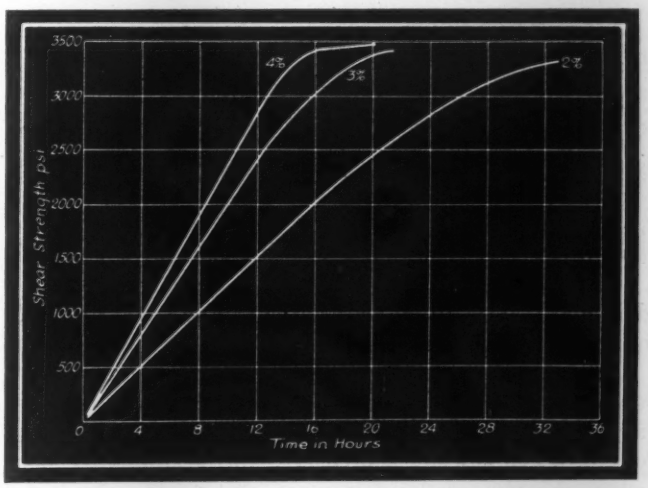


Fig. 4—Curves apply to joints between laminated phenolic sheets bonded with resin adhesive of various percentages of catalyst Z-1A. Cure temperature: 122 degrees Fahr.

adhesion of the cement. As already pointed out, the smoothness and fit of the surfaces to one another will be dependent upon whether solvent or nonsolvent adhesives are employed. The latter type are less critically dependent for their strength upon glue line thickness, whereas with the solvent type the glue line will never develop its full strength so long as a trace of solvent remains.

While shear strengths of 2500 to 3000 pounds per square inch have been obtained in cemented assemblies between laminated phenolics and aluminum strips, complete elimination of rivets and screws from the design may not always appear feasible. Rivets and screws, or some other mechanical means may be used to advantage for protecting the assembly from abuse. They also prove helpful in maintaining contact pressure on the glue lines

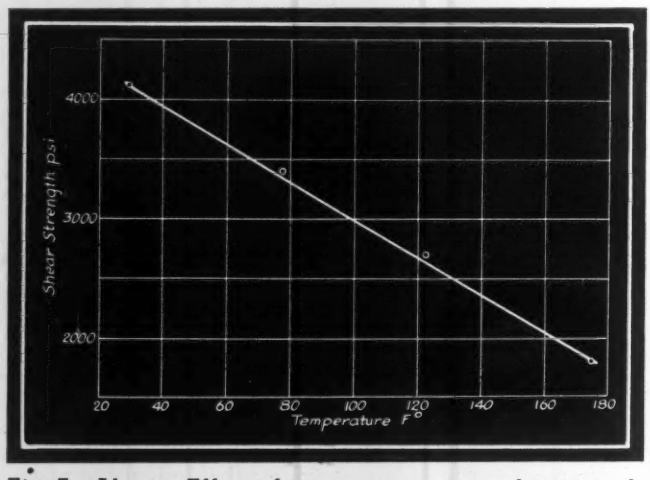
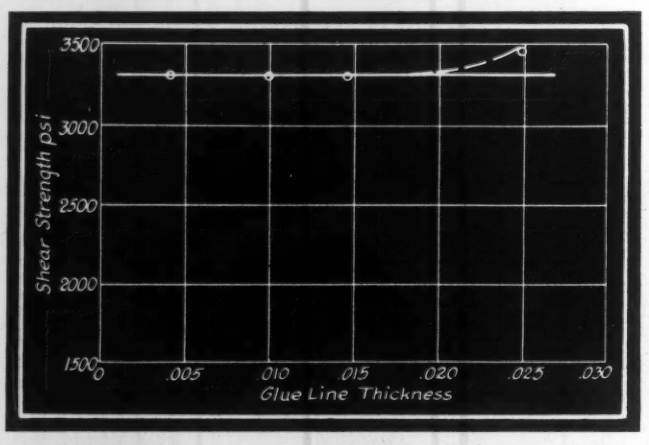


Fig. 5—Above—Effect of temperature on cured joint made between laminated phenolic sheets with resin adhesive

Fig. 6—Below—Graph indicates extremely meager influence which glue line thickness has on joint between laminated phenolic canvas sheets with resin adhesive



during the assembly operations and during the time required for curing the resin adhesive.

Recent studies on stress distribution of cemented joints[1] reveal some interesting data. For thin glue lines, the authors found it convenient to consider the problem as one of a cylindrically bent plate. In the instance of lap joints, the two overlapping sheets are considered as one homogeneous plate with a discontinuous thickness variation and a neutral plane discontinuous at the ends of the joint section. Significantly, the authors conclude that for inflexible cement layers, stress distribution is not critically dependent upon joint dimensions and physical properties of the cement material. Stress concentrations are calculated to be less in the case of relatively flexible types of cements.

It will be seen from the foregoing that these new developments in adhesives may well serve to encourage designers to have more confidence in cemented assemblies. Full application details must be understood before the cements are applied if success is to be expected. For example, some materials, while capable of high strengths, cannot be considered because of high temperatures of cure which are required. On the other hand, others will extend the usefulness of existing materials, such as rubber products and formed laminated phenolic parts, which now can be cemented 100 per cent satisfactorily even at extremely low temperatures.

[1]Goland and Reissner—*Journal of Applied Mechanics*, Vol. 11, A-17, March, 1944.

Aircraft Engines in Tanks

WHEN employed to power tanks, radial aircraft engines offer advantages over liquid-cooled automotive types in weight per horsepower, external contours, dimensional characteristics and freedom from liquid cooling hazards.

This significant comment was made by G. Waine Thomas, executive engineer of Continental Motors Corp. in the presentation of his paper "Aircraft Engines in Tanks" at the recent S.A.E. National Aeronautical meeting in New York.

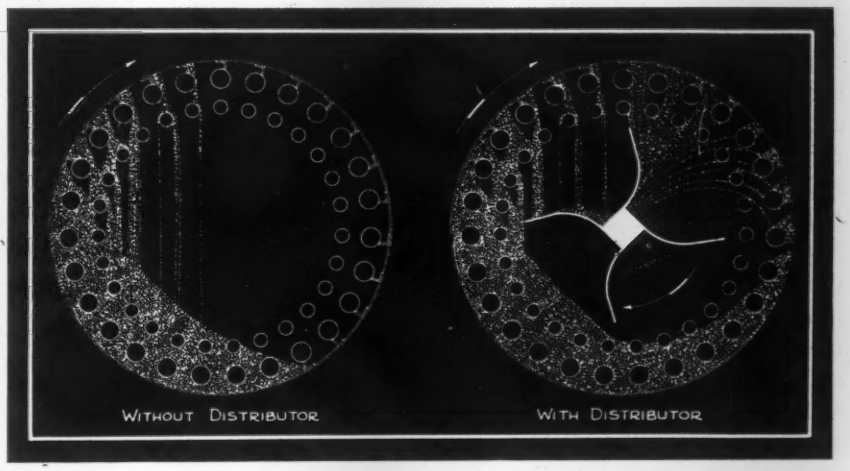
In stressing the less vulnerable nature of air-cooled engines, Mr. Thomas cited an incident from the North African battle zone. A 30-mm shell pierced a cylinder of a W-670 engine in an M3 light tank. In spite of this the engine continued to function, making it possible for the tank's crew to return safely to its base.

Mr. Thomas pointed out that the importance of weight saving in a tank which weighs 60,000 pounds or more can be understood readily when it is realized that the difference in weight between a liquid-cooled engine of the conventional automotive type, using cast iron for the major parts, and an air-cooled aircraft engine can mean a difference in armor plate thickness over the entire tank surface of .15-inch.

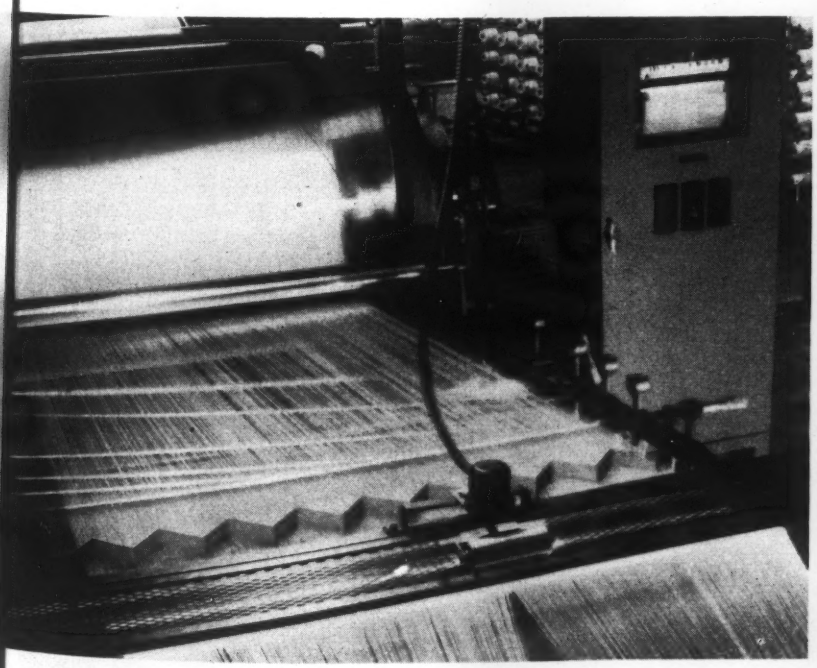
Ease of providing for cooling in the radial air-cooled engine also was emphasized, cooling demands readily being met by a fan running at crankshaft speed and having a diameter somewhat smaller than that of the engine. Cited also was the fact that damage to a liquid-cooling system easily can put a tank out of commission, while severe damage to an air-cooling system has only a slight effect on power plant functioning. From the service standpoint, water supply, especially in desert operation, can be a serious problem. Again, under severe dust conditions, liquid-cooled radiators clog with direct reduction in cooling potential, whereas air-cooled cylinders may clog with only minor loss in cooling efficiency.

Scanning the Field for Ideas

Bottlenecks in steam-tube dryers have been overcome with the introduction of a rapidly revolving "paddlewheel" distributor to increase the drying action of the unit, shown schematically in the drawing at right. By thus utilizing a larger proportion of the available heating surface, the capacity of the dryer is increased by about 25 per cent. The distributor revolves in the same direction as the dryer cylinder but at a much higher speed, that for the distributor being 150 revolutions per minute while that for the cylinder is 3 to 4 revolutions per minute.



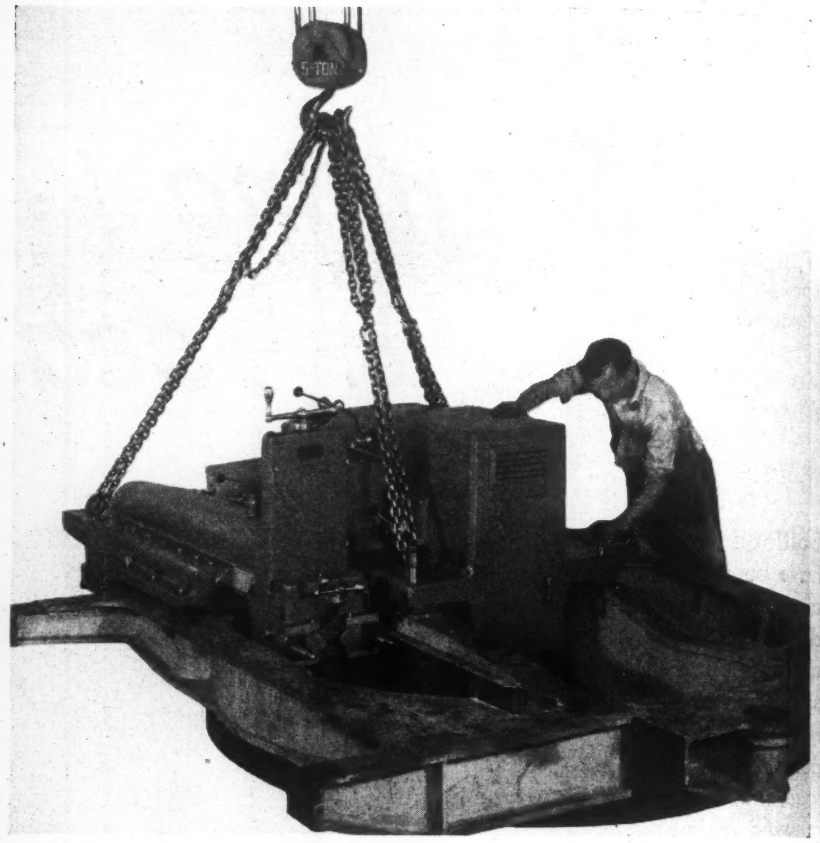
The distributor, driven by a variable-speed motor from the feed end of the dryer, is provided with vanes as shown in the drawing for only two-thirds of its length, at the dry end. It does not extend to the wet end because wet materials entering the dryer would cling to the surfaces of the vanes.



Measurement and control of moisture content of materials such as cotton and rayon is possible with an electronic unit developed by the Brown Instrument Co. Because electrical resistance of the material being processed bears a definite relationship to its moisture content, measurement of resistance may be calibrated to give percentage of moisture. The instrument, known as a Moist-O-Graph, is shown at left applied to a cotton slasher. A small, metal-contact roll rides on the material while a low-voltage, high-frequency current is applied. The amount of current passing through the material to a "ground" roll is a measure of the moisture content. In the installation illustrated, a variable-speed drive, controlled by this instrument,

adjusts the moisture content by varying the speed at which the cotton warp passes through the sizing tanks and over the heated cylinders.

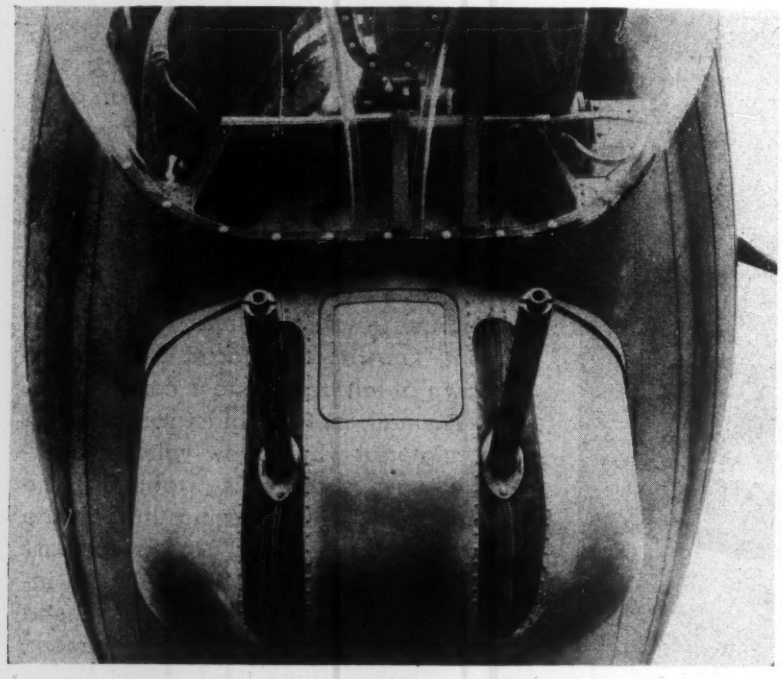
Machining heavy parts has attracted considerable attention to the development of portable machines for special operations. Not only are special tools doing jobs cheaper and with less time but they also are releasing large general-purpose tools for other duties. An excellent example of this is indicated in the illustration at right where a portable hydraulic shaper is bolted to a welded steel base for a gun mount. Machining of pads on this base formerly required a large openside planer. Designed by the Rockford Machine Tool Co., the planer finishes these surfaces within the close tolerances specified. Another application of a special tool, utilized to advantage for reaming shaft flanges, was discussed in this section last month.



Zippers for gun-slots in aircraft make closures possible where other methods were mechanically unfeasible. Such an application, made by the Bendix Products Division, is shown below. Being double acting, the zipper opens just ahead of the gun barrel and closes immediately behind the gun as it travels in the slot. Before the idea became possible it was necessary to develop a new form of zipper tooth so that the sliders could run in opposite directions with equal facility and clear ice formation without undue force being necessary.

Other problems to be taken into consideration, according to the Crown Fastener Corp., one of the makers of these zippers, were the changing angles of the guns as they track through their firing range, aerodynamic loads, weather, wind pressure, mildew and corrosion. The zipper is required to function under all conditions with low power, since the gun actuates the closing mechanism.

For turrets with curved contours and where the gun pivots are not on the true center of the turrets it was necessary to work out a method for making the zipper chain in curves to fit the exact application. The closure employs an aluminum shield around the gun barrel to which are attached the two full-swiveling zipper sliders. This shield is mounted to the zipper chain and supplementary cloth which in turn is bolted to the surface of the turret. The boltholes are grometed between layers of 1/16-inch felt to assure an even friction distribution.



Specifying Variable-Speed Drives

Part II—Electrical

By Colin Carmichael

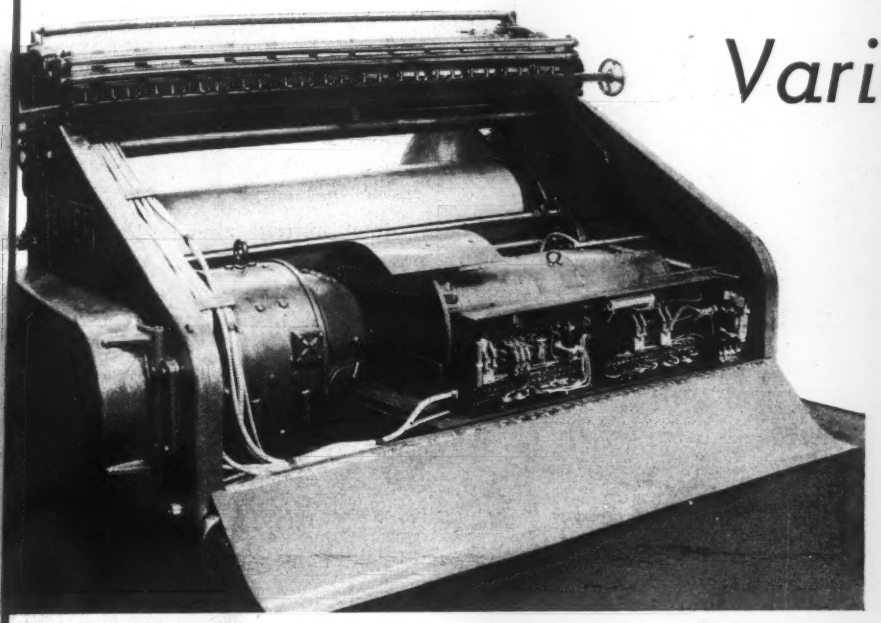
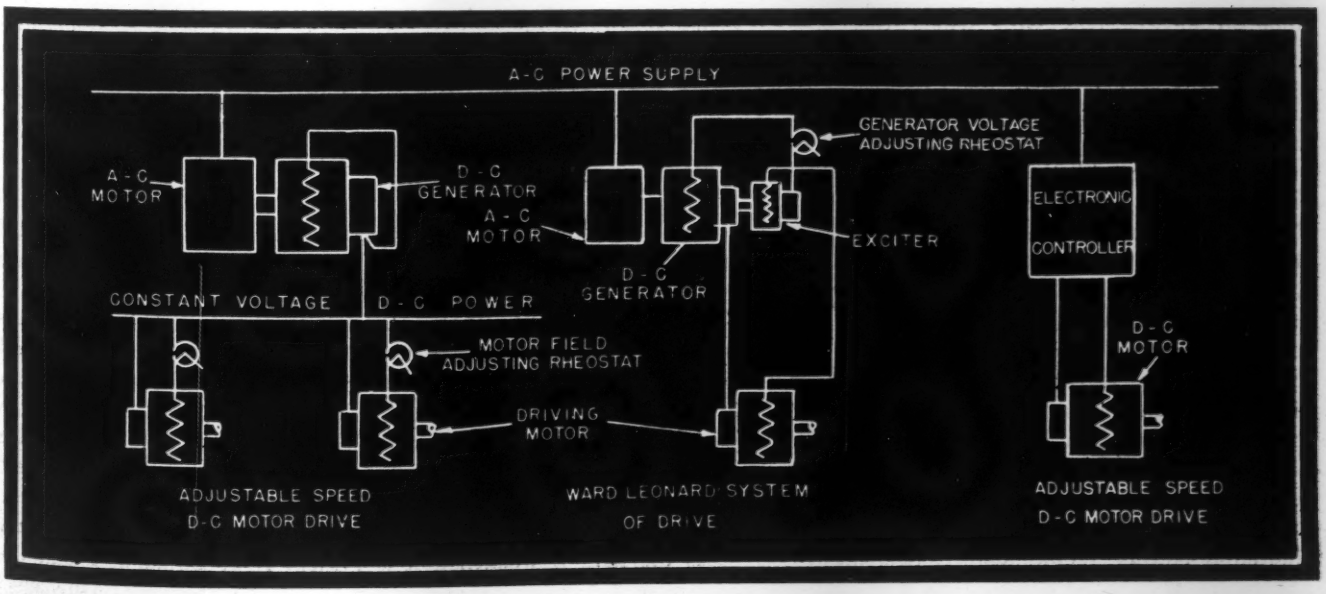


Fig. 1—In this textile mill beamer an adjustable-voltage drive automatically provides speed changes to compensate for 3 to 1 build-up of material on drum

ELECTRICAL methods of obtaining variable speeds fall naturally into two groups—drives and transmissions. Transmissions find their principal use in locomotives, busses and other applications where it is necessary to change the speed and torque ratios between an internal combustion engine and the output driveshaft. Drives, with which this article is chiefly concerned, have potential application to any machine taking power from an electrical distribution system. Inasmuch as alternating current is the source of power in the majority of places where machines are used, the chief problem in electrical drives is how to obtain changeable speed from the fixed frequency of the power system. Typical of the drives discussed in this article is that shown in *Fig.* 1 which illustrates how neatly the necessary equipment can be built into a machine for full enclosure.

In dealing with electrical changeable-speed drives ("changeable speed" being used as an all-inclusive term) a distinction is made between adjustable speed in which the speed, once set, remains nearly constant regardless of load change, and variable speed where the speed is a function of both speed setting and load. A third classification includes multispeed drives in which speed may be changed only in finite steps. The

Fig. 2—Below—Speed-changing systems using d-c motors are shown schematically



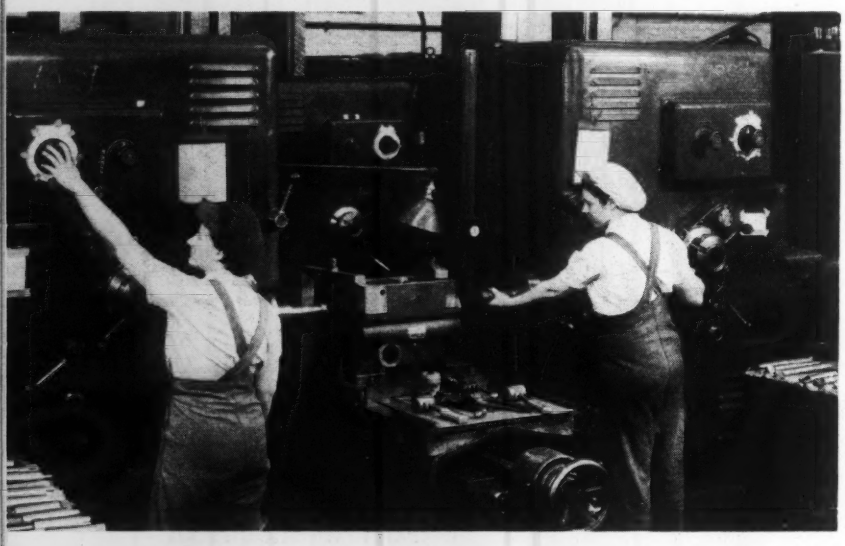


Fig. 3—Special Ingersoll miller for simultaneously machining the ends of aprons for Warner & Swasey lathes employs adjustable-speed drive to give proper tool speeds

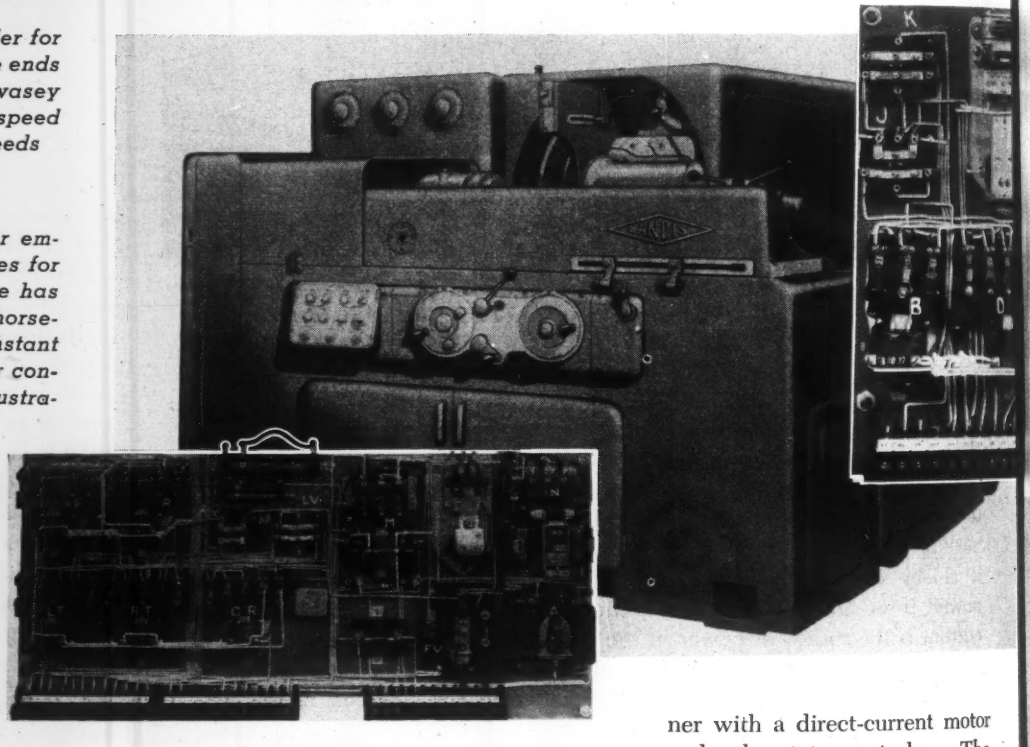


Fig. 4—Right—Thread grinder employs adjustable-voltage drives for wheel and work. Wheel drive has 3 to 1 range at constant horsepower, work drive is constant torque reversing. Main motor control panel at lower left of illustration, and dresser motor control panel at right, are accessible behind their respective doors. All equipment is built into the machine, which is wired for connection to a-c power supply

stepless-change drives with which this article is concerned are, in general, more expensive and less efficient than multi-speed drives but offer advantages such as flexibility which often far outweigh these factors.

Before dealing with the factors that should be considered in selecting and specifying electrical changeable-speed drives, the principal characteristics of the more widely used types will be discussed. While there are numerous modifications of these systems, it is hoped that the review of these typical drives will give the designer a useful picture of the field and assist him in applying the drive most appropriate to the problem at hand. The types of drives available may, for convenience, be classified according to whether the final drive is a direct or an alternating-current motor, with subclassifications according to the method of control:

Direct-Current Motor

a. Constant voltage, direct-current or converted alternating-current power, shunt field control
b. Adjustable voltage, alternating-current power with motor generator
c. Adjustable voltage, alternating-current power with electronic rectifier.

Alternating-Current Motor

a. Wound rotor
b. Commutator
c. Magnetic coupling
d. Variable frequency.

Where direct current already is available from a power line or a motor generator or rectifier, changeable speed can be obtained in a relatively simple manner with a direct-current motor and rheostat controls. The characteristics of the various methods of control may be understood readily from the basic equations for motor speed and torque:

$$N=\frac{K_1(V-IR)}{\phi} \quad \ldots\ldots (1)$$

$$T=K_2\phi I \quad \ldots\ldots (2)$$

where N=motor speed, T=torque, V=terminal voltage, ϕ=field strength, I=armature current, R=armature resistance, K_1 and K_2 are constants. The term $(V-IR)$ is known as the back emf.

As indicated by Equation 1, weakening the field strength ϕ results in speed increase, so that a shunt-wound motor with rheostat field control offers an obvious method of changing speed. The system is shown diagrammatically at the left of *Fig.* 2. Inasmuch as the IR drop through the armature is only a few per cent of the terminal voltage V at any one setting, changes in load which affect I have only a small effect on speed. Such a drive may therefore be classified as adjustable speed, having regulation within ten per cent.

As the field is weakened it is evident from Equation 2 that the

torque decreases. However, the horsepower—which is proportional to the product NT—remains approximately constant as the speed changes, while the efficiency remains high. Standard speed ranges up to 4 to 1 are available and 6 or 8 to 1 can be obtained if special provision is made. On the special dual-head boring, drilling and milling machine shown in *Fig.* 3, drives of this type provide the variety of speeds required by the different tools. It will be noted that temporary paper dials around the rheostat knobs have been specially calibrated with the exact series of speeds required for the particular job being handled.

Adjustable Voltage Offers Practical Method

Adjustable voltage, V in Equation 1, offers the other practical method of changing speed. Inasmuch as this method of control is the basis of many commercial, changeable-speed drives, an understanding of its basic characteristics is of particular interest. The adjustable voltage, naturally, must be furnished by equipment which is individual to the drive. This takes the form of a motor generator or an electronic rectifier which thus becomes the vital link in the utilization of the fixed-frequency alternating-current power for obtaining changeable speed.

Shown schematically at the center of *Fig.* 2, the conventional adjustable-voltage drive consists of a shunt-wound direct-current motor and a shunt-wound direct-current generator driven by an alternating-current motor which also drives a direct-current exciter for both the generator and direct-current motor. In this simple form it is known as the Ward-Leonard system. Modifications of this basic control have been developed to suit the needs of special applications.

Voltage control, obtained by adjusting the generator field, changes the value of V (Equation 1), giving a speed range up to 10 to 1, with basically constant torque because the motor field strength is not changed. However, by adjusting the motor field, which changes ϕ, a further speed range of 4 to 1 is obtainable, giving a total range of about 40 to 1. For this upper speed range, which involves decreasing ϕ for increased speed, the drive has constant horsepower characteristics. Reason for the 10 to 1 limitation in speed range with adjustable voltage is evident from Equation 1. As the voltage V applied at the motor terminals is decreased, the IR drop becomes an increasingly larger percentage of V, hence as I changes with load (Equation 2) the term $(V-IR)$ and hence the speed fluctuate excessively, while in the event of overload the drive has a tendency to stall. Further, residual voltage in the generator makes it impossible to drop V to zero for no load. Within the range indicated, speed regulation is excellent and the drive is strictly adjustable speed.

Adaptable to Wide Range and Close Regulation

Principal applications of this drive have been to machine tools requiring wide speed ranges and close speed regulation, *Fig.* 3, and to textile machines, *Fig.* 1. A modification of the system also is used for electric transmission in busses, where the generator is driven by a gasoline or diesel engine and adjustable-speed motors are connected to the road wheels. In some recent applications an amplidyne serves as the exciter for the generator, giving close regulation, quick response and sensitive control which can be operated by extremely weak controlling signals.

Where an even wider speed range than is furnished by the conventional adjustable-voltage system must be provided, the applied voltage of V at the generator may be increased by the amount of the IR drop as load is applied, so that the induced voltage $(V-IR)$, and therefore the speed of the motor, remains constant at any one speed setting, thus overcoming the limitation on extremely low speeds already discussed. A rotating regulator, mounted as a unit on the adjustable-voltage generator set, is capable of performing this function and will furnish a speed range of 120 to 1. At low speed and light load the voltage required is less than the residual voltage of the generator, but under this condition the regulator reverses the current in the generator field to overcome the residual. In the planer shown in *Fig.* 5 this type of control is used, being associated with regenerative braking which assures stopping and reversing of the planer table at precisely

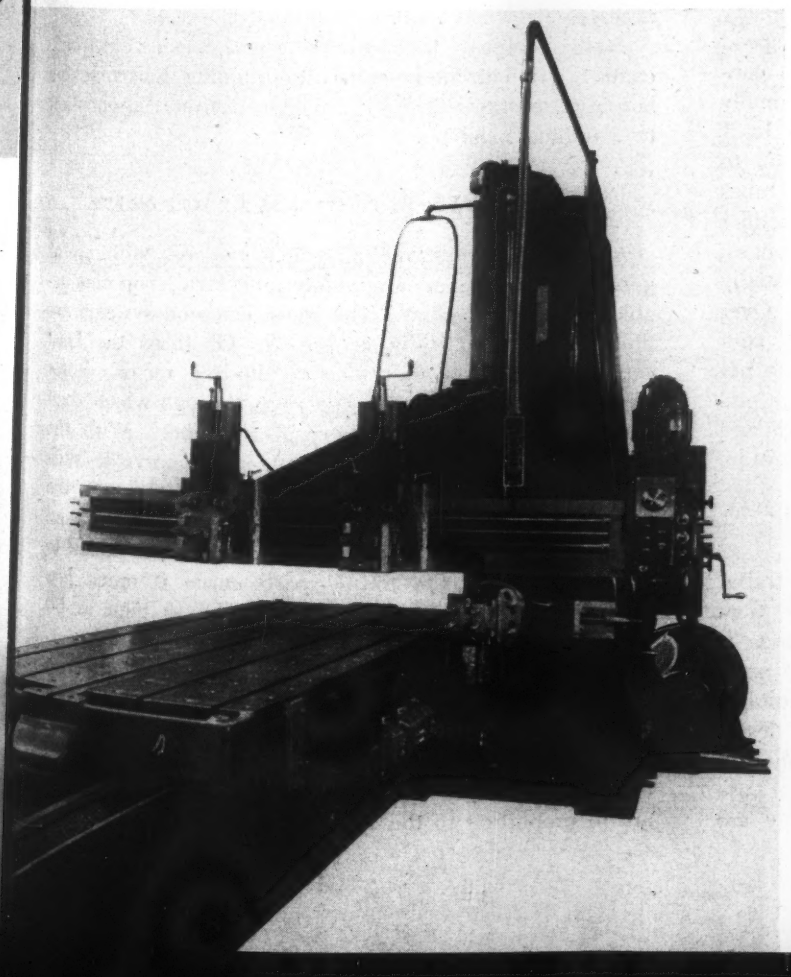


Fig. 5—Left—Rotating regulator, supplementing adjustable-voltage control, provides wide speed range with close regulation on this planer

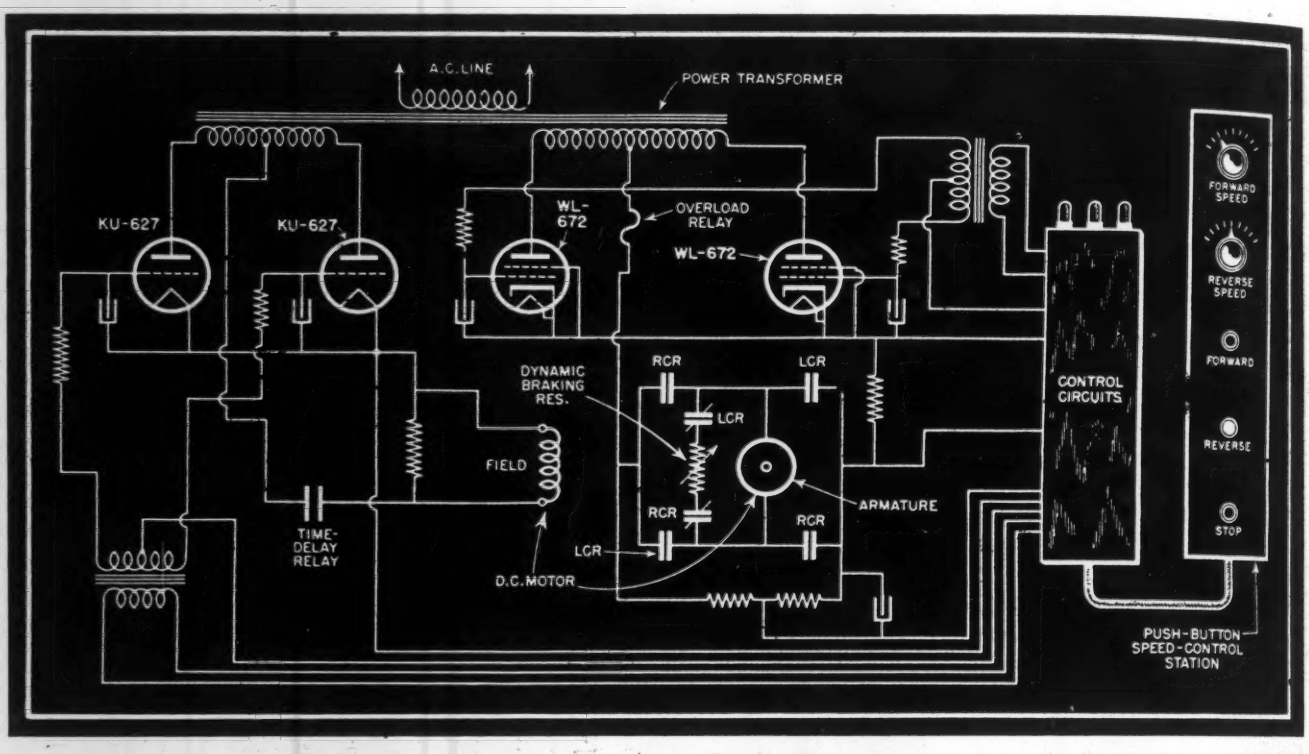


Fig. 6—Schematic diagram shows circuits for electronic adjustable-voltage drive. Two pairs of thyratron tubes supply rectified voltage to armature and field, respectively

the same point every cycle.

Recent developments in adjustable-voltage drives include electronic equipment in place of the motor-generator set. Adjustable voltage is furnished to the direct-current motor by thyratron tube rectifiers. One popular type of unit employs two such electronic tubes to give single-phase full-wave rectification for the armature of the direct-current motor. An additional set of smaller tubes furnishes direct-current power for the field circuit. As in the conventional adjustable-voltage system already described, armature voltage is varied to give speed changes in the lower range while field strength is controlled for higher speeds. Although such units normally are furnished with a speed range of about 20 to 1 below base speed, much larger ranges such as 100 to 1 are possible with this system. Through control tubes the direct-current voltage output of the main rectifier tubes is controlled to compensate for speed changes, regulating motor speed so as to maintain substantially constant speed at any setting regardless of load. Over a 10 to 1 range the regulation is within 4 per cent while over the full 20 to 1 range it is better than 8 per cent. With appropriate controls, different forward and reverse speeds may be preset so that predetermined speeds are obtained in either direction by pushbutton.

Effects of Current Pulsation

Inasmuch as the voltage supplied by the rectifier tubes is pulsating, heating losses in the motor are greater than with regular direct current. When the speed change is effected by grid control which retards the firing point of the rectifier tube, reducing the armature voltage, the pulsation is even greater, while the resultant losses are less easily dissipated at the lower speeds due to poorer ventilation. For these reasons motors for use with electronic adjustable-voltage control ordinarily are furnished on frames a size or two larger than standard constant-speed direct-current motors of equivalent rating. The increase in frame size is less when three-phase rectification is used because of the decreased pulsation compared with single phase. For certain electronic controls now available it is claimed that oversized motors are unnecessary.

More compact than motor generators, electronic controls are admirably suited to building into machine housings, as shown in *Fig.* 7, which illustrates application to a milling machine.

Changeable-Speed Alternating Current Motors

Alternating-current motors which dispense with motor generators or rectifiers are widely used for certain changeable-speed applications. The more common systems are illustrated schematically in *Fig.* 8. Of these the least expensive is the wound-rotor or slip-ring motor. Rotor windings are connected to slip rings through which their current is carried to an external resistance. With the winding short-circuited, the torque-speed curve is such that high torque is obtained with small slip, hence the motor operates only slightly under synchronous speed even at high load. However, when resistance is added to the rotor circuit, the torque-speed curve is much less steep and at full load the slip may be as high as 50 per cent, giving a two-to-one speed ratio.

Inasmuch as speed is a function of torque, accurate control is difficult and as soon as the load is removed the speed returns to its maximum value regardless of the speed setting. This type of drive should therefore be classified as strictly variable speed. Power losses, which are in proportion to the speed reduction, are fairly high,

the efficiency being approximately 30 per cent at half synchronous speed. Wound-rotor motors are widely used for driving fans, pumps and other applications where the load is not subject to much variation and where the torque tends to decrease at lower speed so that power losses are not excessive. Available in sizes from fractional to several thousand horsepower, the wound-rotor motor has the advantages of simplicity and low first cost, compared with most other changeable-speed drives.

Where an alternating-current motor with improved regulation and wider speed range is required, a commutator motor may be used. A speed range of 3 or 4 to 1 is readily obtainable, with speed regulation about 25 per cent at the lowest speed in single-phase models.

Much closer speed regulation is obtained with three-phase commutator motors. In the drive shown in *Fig.* 9, for example, the characteristics in general are comparable with those of a direct-current motor with adjustable-voltage control. A regulator applies to the brushes three-phase voltage which can be made to buck or reinforce the voltage generated in the rotor by the revolving field. When the bucking voltage exactly balances the generated voltage no current flows in the rotor windings and no torque is developed. As the bucking voltage is reduced, current begins to flow in the rotor winding, developing a torque which causes the rotor to turn in the direction of the revolving field. Equilibrium speed of the rotor is that at which the generated voltage is slightly higher than the bucking voltage applied to the brushes. By reversing the voltage furnished by the regulator so that it reinforces the generated voltage the motor may be operated at speeds above synchronous. Because field strength is practically constant, the drive is basically constant torque.

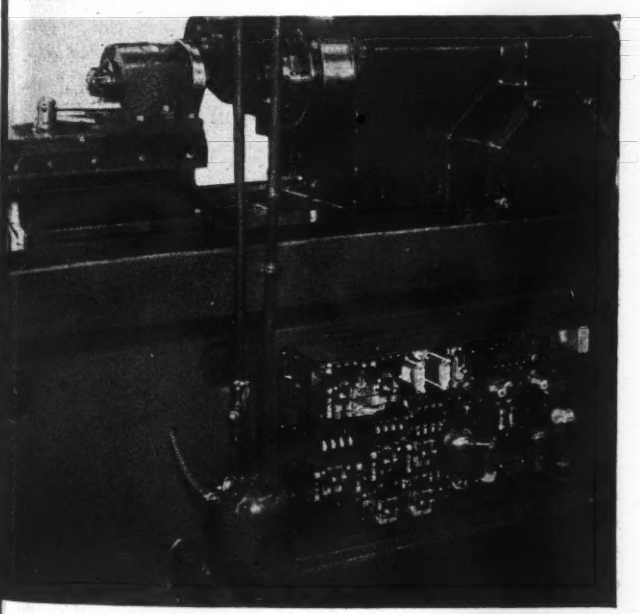


Fig. 7—Above—Built-in electronic control panel on milling machine provides rectified adjustable - voltage for speed control

Using a Slip Coupling for Speed Change

A constant-speed alternating current motor, either synchronous or induction, in conjunction with an electromagnetic coupling or slip-clutch offers a wide speed-range drive which is particularly suited to the operation of fans or any device on which load drops rapidly with speed and is fairly steady. The coupling has speed-torque characteristics similar to those of the wound-rotor motor and, with the necessary auxiliary devices, can be made to operate at constant torque over a 4 to 1 speed range with regulation comparable to that of the adjustable-voltage direct-current drive, thus placing it in the adjustable-speed class. Also, speed may be reduced to zero for inching or jogging. Direct-current excitation must be provided by a motor generator or rectifier. As in the wound-rotor motor, power is dissipated in the clutch when operating at less than full speed, hence it should be provided with an adequate supply of cool clean air for ventilation. Typical applications include printing presses, textile machinery, grinders, paper machines and machine tools. Couplings of this type are quite extensively used on marine diesel drives to serve as a clutch and shock-absorbing coupling between the engine and the reduction gear.

For extremely high speeds—15,000 to 20,000 revolutions per minute—where commutation difficulties discourage the use of direct-current motors, alternating-current motors supplied with changeable frequencies may be used. A source of variable frequency, usually an alternator driven by an adjustable-speed motor, must be provided. The alternator and alternating-current

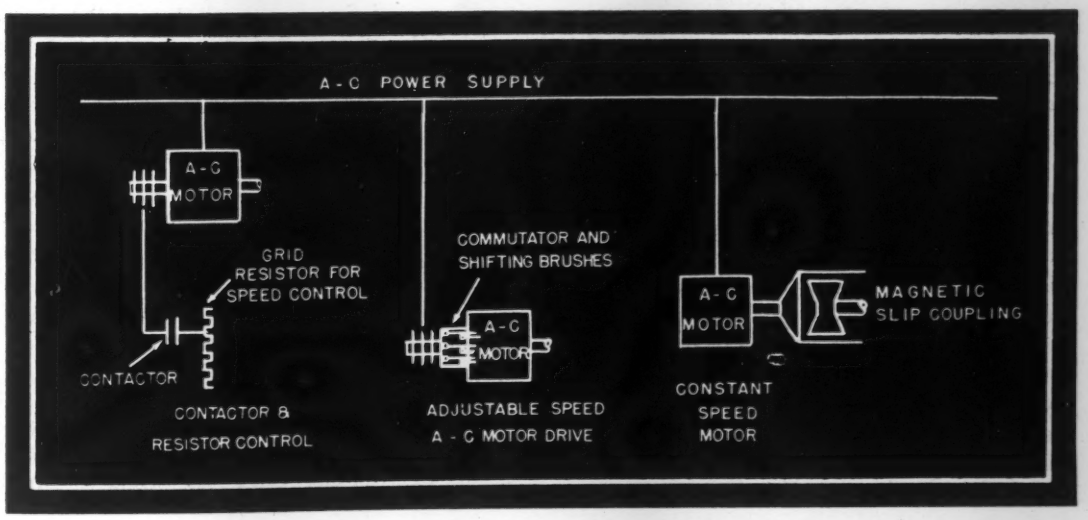


Fig. 8—Right—Speed - changing systems using a-c motors illustrated schematically

motor function in effect as a fixed ratio step-up speed unit between the low-speed drive and the driven unit. The variable-frequency drive also is advantageous for controlling large groups of motors operating together at the same speed. Speed range of 3 or 4 to 1 is practicable.

Factors to be considered in choosing a drive are many, of which the most important are outlined in the following:

SPEED RANGE: Before deciding that a stepless speed-change drive is necessary, the possibility of using a multispeed motor with its inherently high efficiency should be investigated. If stepless changes are needed, the range should by all means be adequate for the job but it is poor practice to provide more than is necessary, because the narrower the speed range, the less the initial cost, the better the performance and the less the attention and maintenance necessary.

Drive Should Operate at High Speed

TOTAL SPEED REDUCTION: If the top speed of the driven machine is low or moderate, a speed reduction drive (gearing, belting or chain) may be interposed between it and the changeable-speed unit so that a smaller, less expensive drive can be used. Further, most drives operate at the high speeds with better regulation and higher efficiency.

TORQUE REQUIREMENTS: Drives are rated in horsepower at top speed but must be selected on the basis of the horsepower required at bottom speed or of the maximum torque at any point in the range, because it is the maximum torque that determines size. If the torque required does not change much with speed, practically any of the drives discussed will perform satisfactorily, inasmuch as most of them have inherently constant-torque characteristics. When the turning effort may increase at low speed as on machine tools and on winder drives where the diameter increases with constant tension as the speed goes down, it is necessary to apply the more expensive constant-horsepower drive. For example, a constant-horsepower drive with a 3 to 1 speed range would be three times as large and have three times the capacity at top speed as the constant-torque drive rated the same at top speed. In any of the drives discussed, starting-torque requirements usually can be met without difficulty.

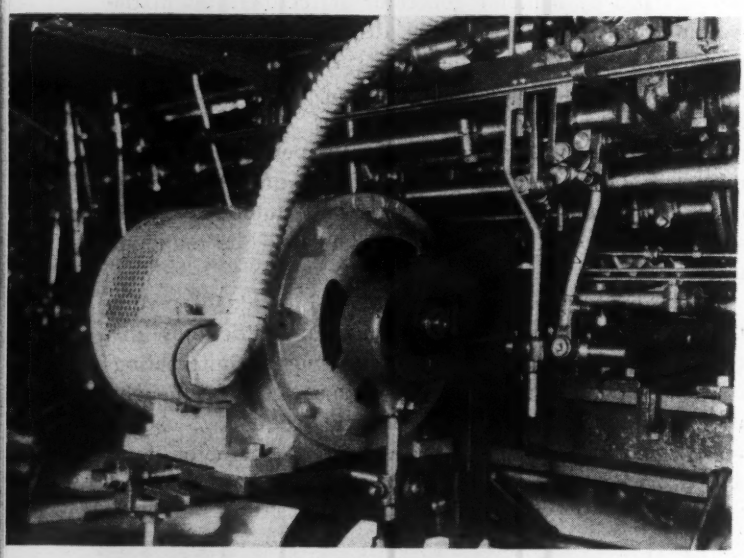


Fig. 9—Adjustable-speed three-phase a-c commutator motor provides 3 to 1 speed range for full-fashioned hosiery machine drive, as well as inching for adjustment and set-up

TORQUE VARIATION: At a given speed setting, torque may be pulsating or may be subject to variation. In general, electrical drives are well adapted to shock, impact or pulsating loads. However, when torque varies, an adjustable-speed rather than a variable-speed drive may be necessary if close regulation is desired.

START, STOP AND REVERSE: Frequency of starting and stopping, electrical braking and reversing requirements influence the selection of drives. A fully reversible drive may be unnecessary when a simple ability to back-up is all that is required.

ACCELERATION: Rate of speed change may be a factor which should be considered, and may require torque values during the period of acceleration which necessitate modification of a standard drive.

JOGGING: Slow speeds for set-up, creeping, inching or jogging are requirements which some but not all drives can satisfactorily meet. It may be desirable to make other provision for this feature, such as by the use of a separate clutch.

CONTROL: Remote control of speed as well as of starting and stopping may be electrical or mechanical, the latter being suitable only for short distances and for one control station.

MULTIMOTOR DRIVES: Certain applications involve synchronizing a given unit or series of units with the rest of the process. In such cases speed must be controllable either by individual machines or in groups of machines—a condition which some but not all drives can successfully meet.

Compare Costs of Alternative Systems

POWER SUPPLY: If direct-current power only is available, the natural choice of drive is a direct-current shunt-control system. However, if both alternating and direct-current power are available, it is well to compare the cost with voltage control.

AMBIENT CONDITIONS: Heat, dust or fumes will vitally influence the selection of the drive. Under such conditions a protected drive or external ventilation must be used.

Although the types of drives discussed in the foregoing cover the great majority of applications, there is a multitude of types and minor variations of types on the market—each of which has certain features or characteristics which make it better than any other for specific applications. By furnishing the manufacturer with complete details of the machine or process to be controlled, the designer can be assured that the drive which is recommended and finally selected will satisfactorily meet all operating conditions.

MACHINE DESIGN acknowledges with appreciation the cooperation of the following companies in the preparation of this article: Crocker-Wheeler Electric Mfg. Co. (*Fig.* 9); General Electric Co. (*Figs.* 2, 7 and 8); Reliance Electric & Engineering Co. (*Figs.* 1 and 4); Weltronic Co.; Westinghouse Electric & Mfg. Co. (*Figs.* 5 and 6).

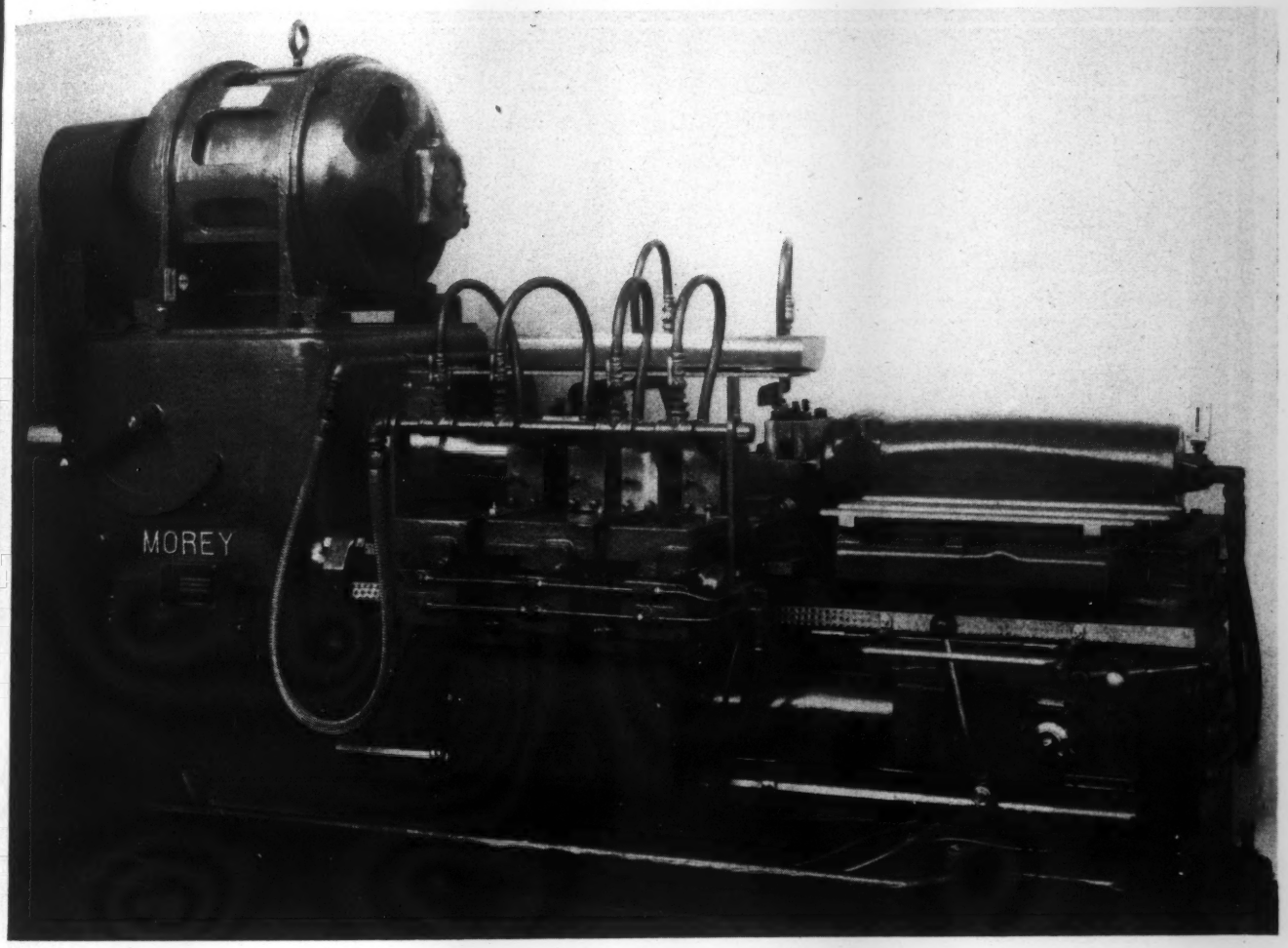


Fig. 1—Hydraulically operated, this semiautomatic lathe utilizes unit-base construction for the necessary rigidity

Sequence Control Facilitates Production

By Robert Kurzweil
Morey Machinery Co., Inc.

HYDRAULIC feeds and controls, completely automatic except for loading and unloading, are utilized in the semiautomatic shell lathe illustrated in *Fig.* 1. In contrast to the conventional design of providing two legs under the headstock and tailstock, respectively, the whole machine rests on one base. This gives the machine the rigidity necessary for its job, making possible the machining of shells which may be eccentric up to ½-inch on the diameter. In the base are two tanks separated by a cast wall, one being for hydraulic oil and the other for cutting lubricant. The cutting lubricant is supplied to the cutting tools individually through a system of pipes and hoses with flow-control valves provided for each tool.

Movement of one lever operates the complete chucking cycle, bringing the tailstock into working position, moving the tailstock towards the shell, and locking the work to the arbor. A second lever starts the feeding cycle—engaging the headstock clutch, bringing the tools into working position and starting the feeds on front carriage and rear slides. Adjustable stops are provided on the front carriage which automatically stop the spindle and withdraw all tool slides, bringing them to the original starting position after the cycle is completed. After the arbor is released the tailstock is withdrawn and the shell is ready for unloading. The hydraulic system for these operations is shown schematically in *Fig.* 2, while *Fig.* 3 illustrates the electrical control diagram.

Hydraulic power for both the chucking and feeding cycles is supplied by a combination high and low-pressure pump. Advantage is taken of

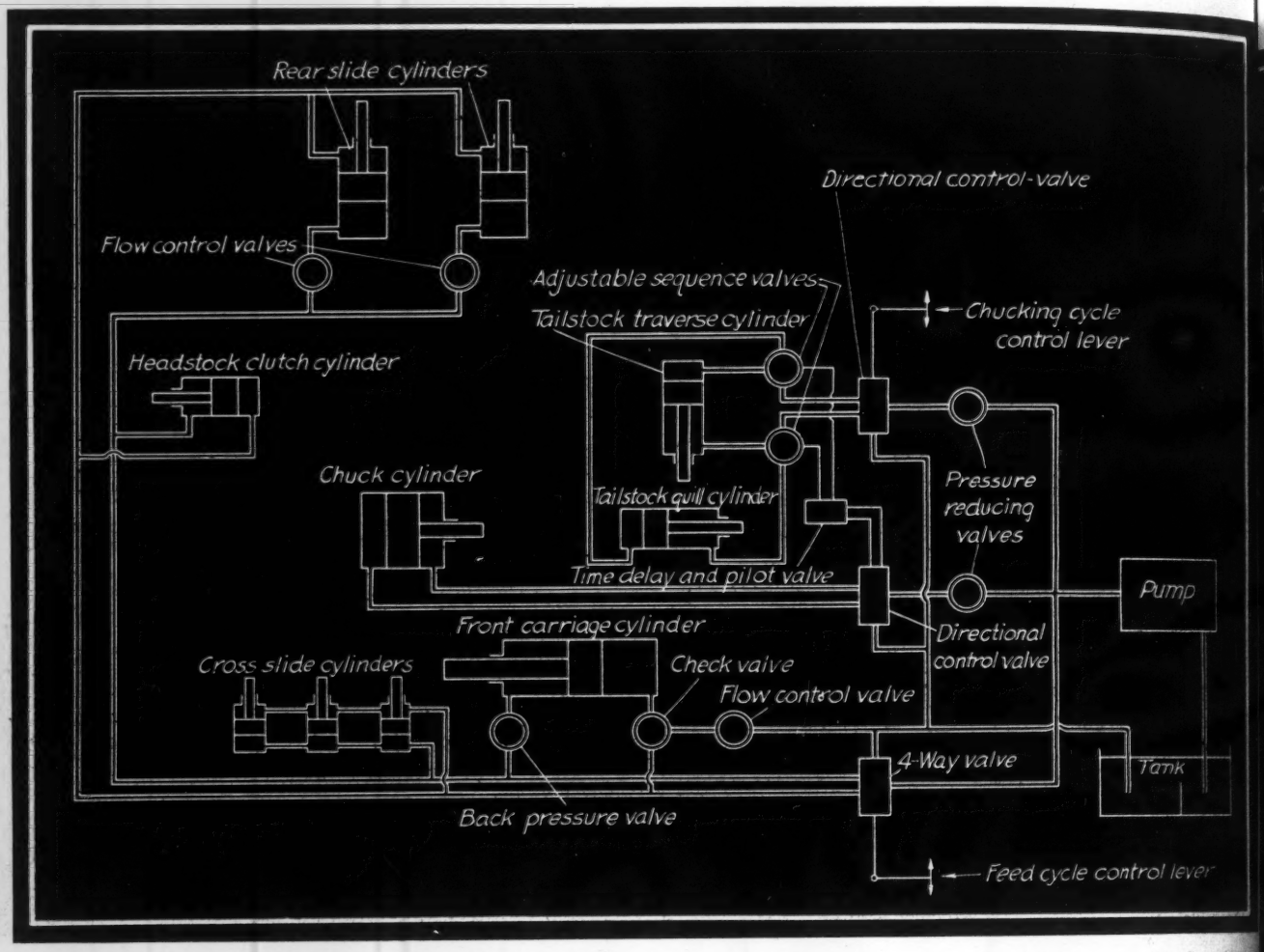
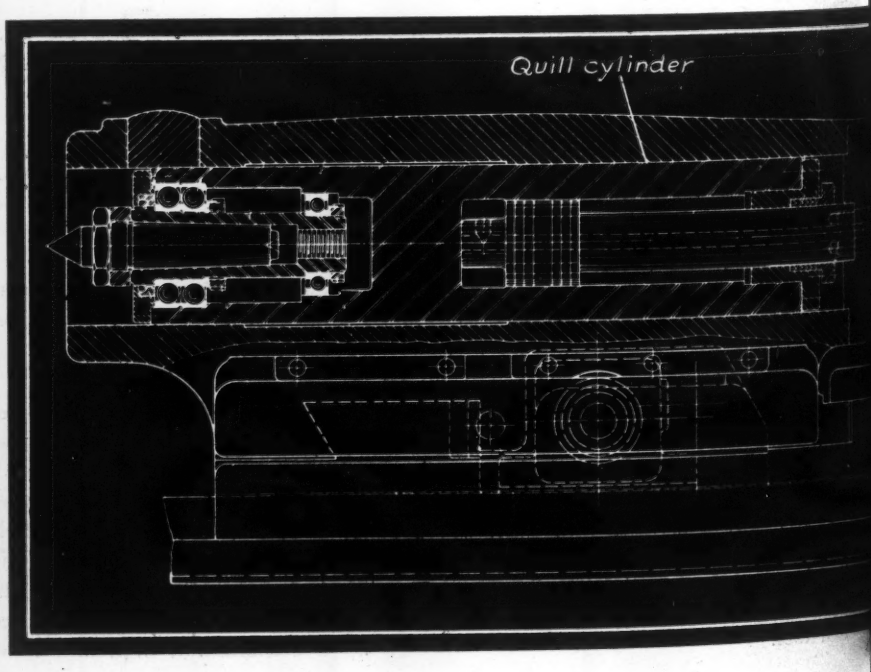


Fig. 2—Above—Schematic diagram of hydraulic circuit showing cycle control

the fact that these two cycles do not operate at the same time, making it possible to obtain sufficient power with a combination pump driven by a three-horsepower motor. This pump provides for rapid approach of all slides until the resistance increases and pressure builds up, causing automatic switching to the high-pressure, low-volume pump.

One of the outstanding features of the machine is the transverse movement of the tailstock which makes possible the sliding of the shells to the arbor without lifting and the removal of finished shells to a conveyor. The tailstock transverse cylinder, the tailstock-quill cylinder and the chucking cylinder must be operated in the correct sequence. It is necessary that the transverse cylinder be in place before the tailstock-quill cylinder starts moving forward. Only after both are in working position can the shell be locked to the arbor. Adjustable sequence valves in the hydraulic circuit for these cylinders assure proper sequence.

The built-up pressure in the cylinders operates a combina-



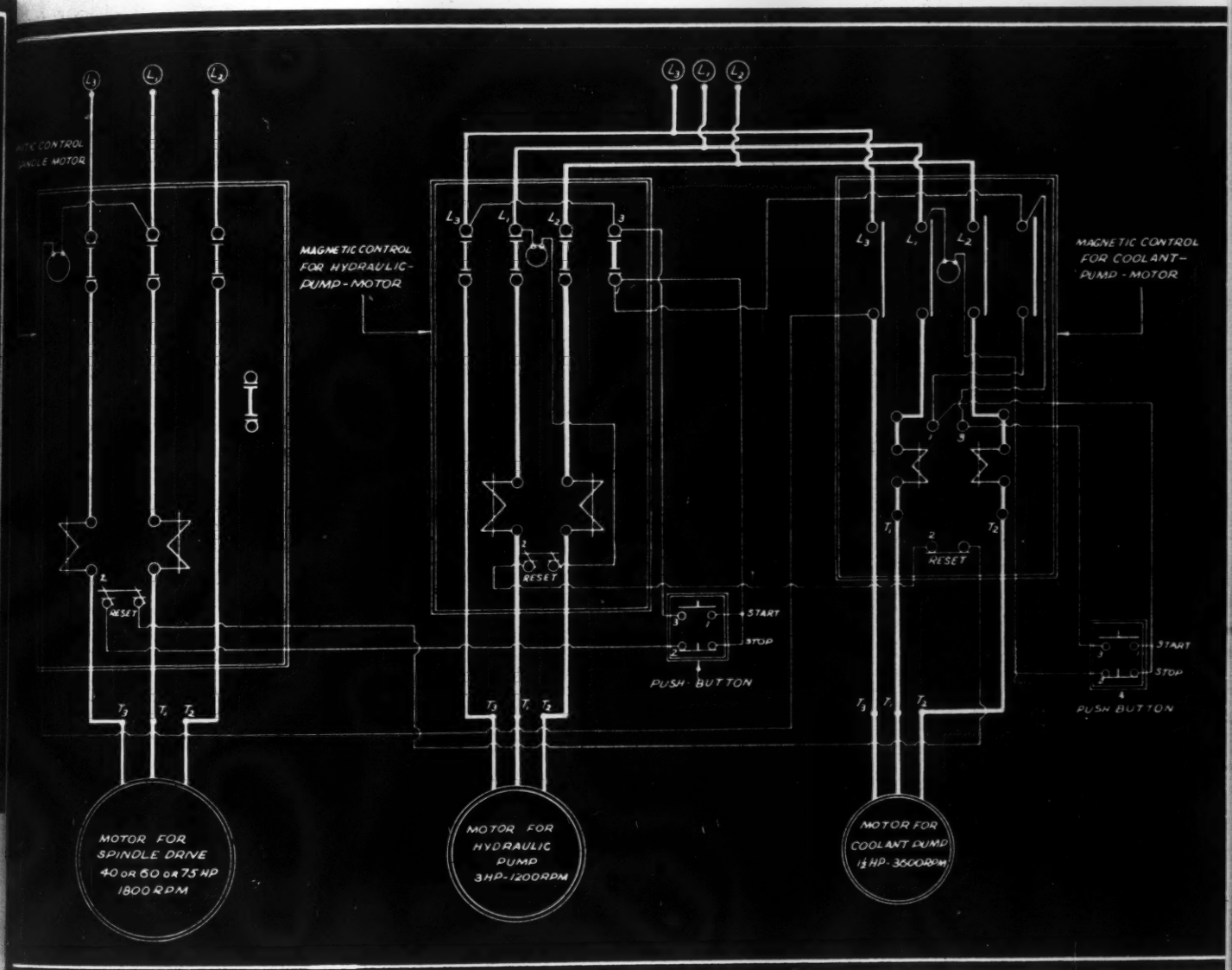

MAGNETIC CONTROL FOR HYDRAULIC-PUMP-MOTOR
MAGNETIC CONTROL FOR COOLANT-PUMP-MOTOR
RESET
START
STOP
PUSH BUTTON
MOTOR FOR SPINDLE DRIVE 40 OR 60 OR 75 HP 1800 R.P.M.
MOTOR FOR HYDRAULIC PUMP 3 HP-1200 R.P.M.
MOTOR FOR COOLANT PUMP 1½ HP-3600 R.P.M.

Fig. 3—Above—Electrical circuit diagram for the hydraulic pumps and magnetic controls

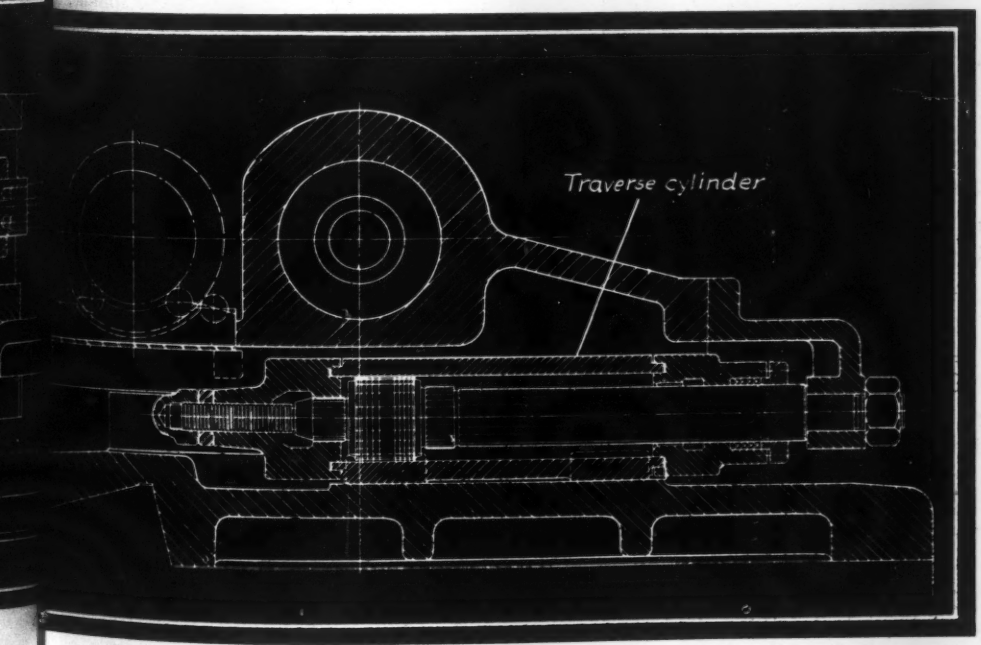


Fig. 4—Left—Tailstock design incorporates two hydraulic motions, one for the quill and the other for transverse motion

tion time-delay and pilot valve with a fixed setting, giving a time delay of two seconds. This valve actuates the directional control for the movement of the chuck cylinder. Hydraulic pressure on the tailstock and chuck cylinders can be reduced independently with two pressure-reducing valves. This adjustment is necessary for the different chucking pressures required for rough or finish turning operations.

Front carriage is equipped with three cross slides for taper or contour turning over the full turning length. Each of the three cross slides is moved transversely by a hydraulic cylinder and is equipped with rollers mounted on two needle bearings. These three hydraulic cylinders have a bore of 2¼ inches and use a hydraulic pressure of 1000 pounds per square inch. The rollers are held against the cam bar by hydraulic pressure of approximately 4000 pounds. No mechanical lock is used to hold the cross slide against the cam bar. This principle in design was particularly successful on the rough turning operation of extremely eccentric shells where other machines using mechanical cross-feed failed. For finish turning operation, close tolerances can be maintained.

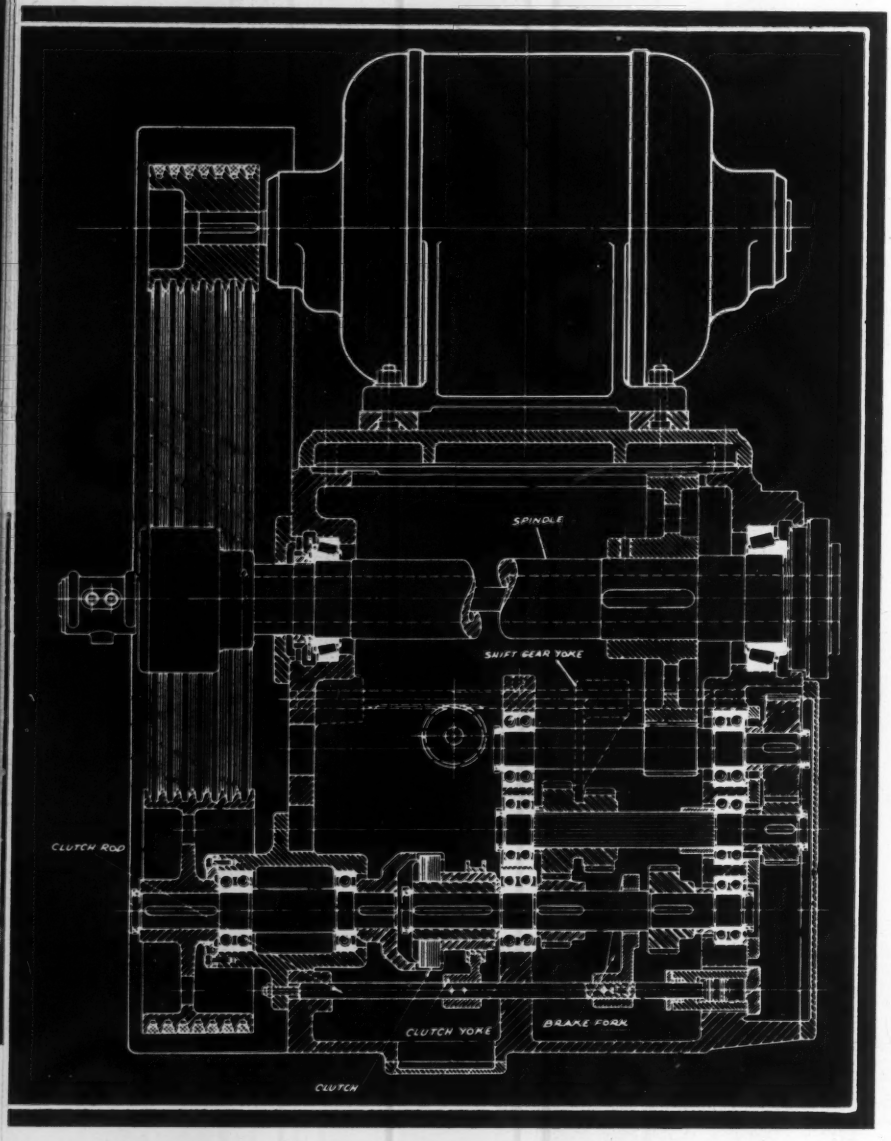


Fig. 5—Sectional view of headstock showing pickoff gears and shifter arrangements

Longitudinal movement of the front carriage is actuated by a hydraulic cylinder with a 5-inch bore. The size of this cylinder was determined by the finest feed required for this type of machine. Experience has proved that a minimum feed of .005-inch per revolution can be maintained within the speed range of the machine.

The metering-out principle is used for controlling the feed rate on the front carriage, by using a check valve and a flow-control valve in the return line to the tank. An adjustable back-pressure valve is provided in the input line for the feed cylinder in order to obtain a constant speed on the return stroke, independent from the setting of the flow-control valve.

Two rear slides for facing and cutoff operations are equipped with built-in hydraulic cylinders. The feed rate of each rear slide can be independently controlled by a flow-control valve. Directional control is operated simultaneously with the front carriage from the lever-operated, 4-way valve, giving a completely automatic feeding cycle. The relative position between the piston rod and the rear slide can be adjusted, which makes it possible to bring the cylinder to the end of the stroke in the forward position. Adjustable stops are provided for return.

Spindle of the lathe is driven by a 75-horsepower motor through V-belts, a multiple-disk clutch, pick-off gears and a bull-gear drive. The headstock clutch is actuated by a hydraulic cylinder which simultaneously engages a brake as soon as the clutch is released and vice versa. This clutch cylinder is controlled by the same directional control valve which actuated the feeding cycle.

An expanded section through the headstock drive is illustrated in *Fig.* 5. The spindle, mounted on high-precision, tapered-roller bearings, has a 3-inch hole for the operation of the expanding mandrel by a hydraulic cylinder on the end of the spindle.

Some of the features of the tailstock, *Fig.* 4, are mentioned in the chucking cycles previously discussed. The piston of the tailstock-quill cylinder is stationary while the quill cylinder (which is at the same time the tailstock quill) moves in and out by hydraulic pressure. Work is supported on a live center, built as an integral part of the tailstock quill. The tailstock is held against the work by hydraulic pressure and mechanical locks again are unnecessary.

The tailstock transverse cylinder is equipped with a built-in hydraulic cushion to prevent any shocks on the side movement of the tailstock. Alignment of the tailstock with the center line of the spindle can be adjusted by a fine-pitch screw which is located inside the tailstock cylinder. In the loading position, two bars on the tailstock form the slide over which the shells can be moved on to the arbor without any elevation.

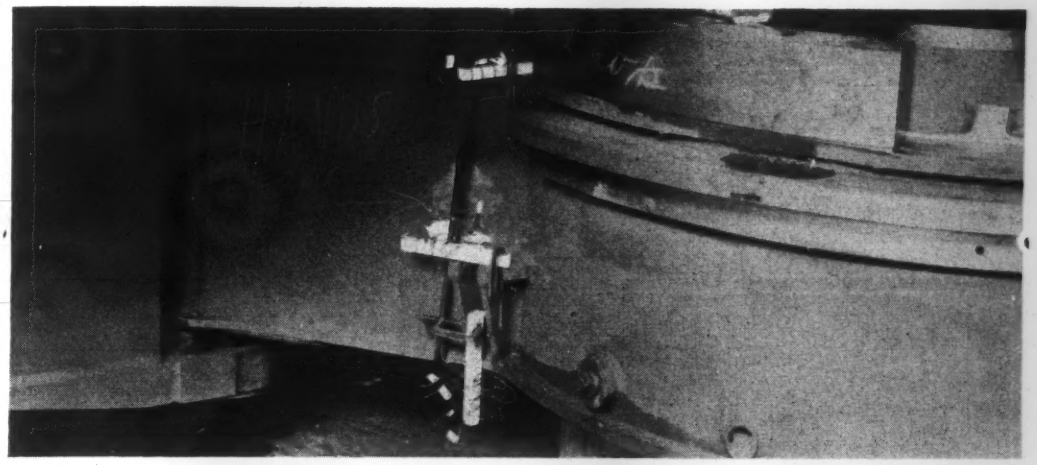


Fig. 1—Rosette of three gages at 60-degree angles on the trail hinge bracket of a 24-millimeter howitzer. Shear stresses are brought about by direct shear force and by torsion from a loading beam located above the carriage. In view of the complexity of the structure, strain-rosette analysis was found valuable in checking the accuracy of the calculations

Graphical Method Simplifies Strain-Rosette Analysis

By J. H. Meier
Research Engineer
Bucyrus-Erie Co.

STRAIN-rosette analysis is becoming increasingly important in the study of strains and stresses in complicated machine parts (1)* such as shown in *Fig.* 1. The introduction of resistance-wire strain gages (2) has greatly facilitated rosette analysis and, properly interpreted, the results from wire gage rosettes have been exceptionally accurate.

In general, compensation has to be made for the transverse strain sensitivity of wire gages used as elements of a rosette. In the following, the effect of this sensitivity is analyzed and a simple method is outlined for constructing the Mohr's circle for true strains.

Strain sensitivity of the filament (a physical property of the material) and specific transverse sensitivity of the gage (a function of the geometry of the filament configuration) appear separately in the formulas. This simplifies the problem substantially and greatly reduces the amount of test work required to establish the factors necessary for interpretation. It is assumed throughout this discussion that the field of strains covered by the rosette is uniform.

Wire strain gages generally are made up of several loops (3) to obtain favorable electrical characteristics. Since parts of the filament are not parallel to the axis of the gage, the reading will be influenced by strains both parallel and normal to the axis of the gage. If the arrangement of the sensitive filament fulfills certain geometrical conditions, the reading of the gage can be expressed as

$$R_c = F_a\epsilon_a + F_n\epsilon_n \quad \ldots\ldots (1)$$

Gages that can be split into pairs of elements with bisectrice parallel to the axis of the gage satisfy the geometrical requirements and respond (10) according to Equation 1. Therefore, gages with axial symmetry of the wire configuration work in this manner. All flat wire gages now commercially available fall in this category.

The sum of the axial and transverse strain sensitivities

THIS GRAPHICAL METHOD of determining corrections for transverse gage sensitivity was developed by the author while working on design calculations for the Ordnance Department. Simplicity of the procedure offers many advantages over other methods, obviating the need for complicated tests to determine gage constants

*References in parentheses are listed at end of article.

of a compound-wire gage, which conforms to Equation 1, can be proved to be equal to the strain sensitivity of the wire, i.e.,

$$F_a+F_n=F \quad \ldots\ldots (2)$$

This is visualized readily when a compound gage in a field of uniform strain in all directions is considered. Each

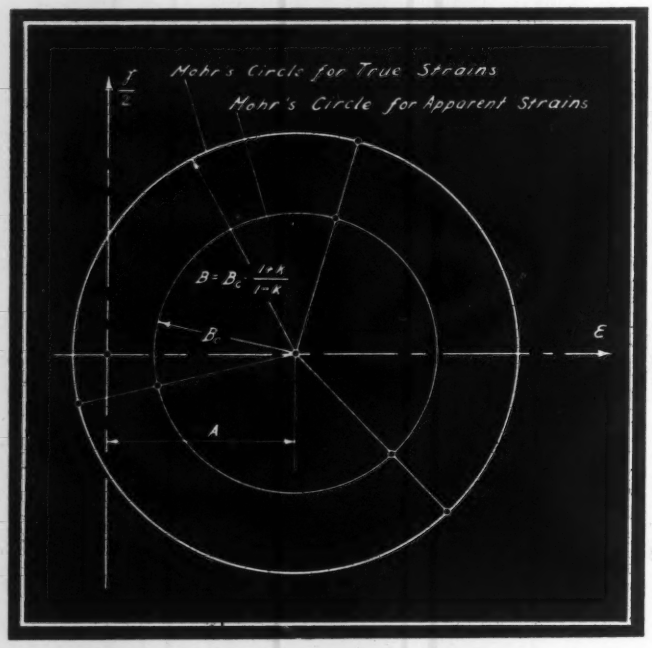


Fig. 2—Rotations between ϵ_{max}, ϵ_{min}, A, B, ϵ_a, ϵ_n and α derived from Mohr's circle for true strains

element of wire is then subjected to the same strain. The reading is the same as if the wire were a single straight filament for which the strain sensitivity factor is F.

Strain Gage As Rosette Element

According to the Mohr's circle theory, the normal strain along an axis forming an angle α with the direction of the algebraically greater principal strain, *Fig.* 2, can be expressed as

$$\epsilon_a=A+B\cos 2\alpha \quad \ldots\ldots (3)$$

The strain at right angles to the direction of the axis is

$$\epsilon_n=A-B\cos 2\alpha \quad \ldots\ldots (4)$$

Reading of a gage consisting of a single straight filament is determined by Equation 3 and the strain sensitivity factor of the material:

$$R_s=F\epsilon_a=FA+FB\cos 2\alpha \quad \ldots\ldots (5)$$

Compound-gage reading is established by applying the corresponding strain sensitivity factors to the strains ϵ_a and ϵ_n determined by Equations 3 and 4, namely,

$$R_c=F_a(A+B\cos 2\alpha)+F_n(A-B\cos 2\alpha)$$

or,

$$R_c=(F_a+F_n)A+(F_a-F_n)B\cos 2\alpha$$

and recalling Equation 2,

$$R_c=FA+(F_a-F_n)B\cos 2\alpha \quad \ldots\ldots (6)$$

True strain is obtained by dividing the reading of the single straight-wire gage by F. Comparing Equations 5 and 6, it can be seen they both contain the product FA. It seems logical therefore to define the apparent strain as being obtained by dividing the reading of the compound gage by F.

According to Equation 5 the true strain is obtained from the single straight-wire gage as

$$\epsilon_s=\epsilon_a=\frac{R_s}{F}A+B\cos 2\alpha \quad \ldots\ldots (7)$$

The apparent strain indicated by the compound-wire gage is found from Equation 6 as

$$\epsilon_c=\frac{R_c}{F}=A+\frac{F_a-F_n}{F}B\ \cos\ 2\alpha$$

and recalling Equation 2,

$$\epsilon_c=\frac{R_c}{F}=A+\frac{F_a-F_n}{F_a+F_n}B\ \cos\ 2\alpha$$

or

$$\epsilon_c=\frac{R_c}{F}=A+\frac{1-k}{1+k}B\ \cos\ 2\alpha \quad \ldots\ldots (8)$$

Equations analogous to 7 and 8 can be established for

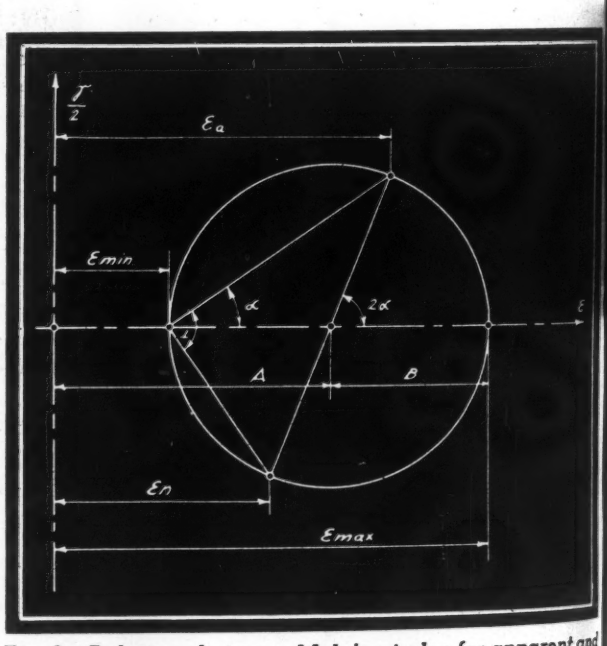


Fig. 3—Relations between Mohr's circles for apparent and true strains

the other gage directions of a rosette, the only factor to be changed being α.

Now with two Mohr's circles, one for the true strains ϵ_a obtained from a rosette consisting of single straight-wire gages, and the other for the apparent strains ϵ_c obtained from a rosette made up of compound gages, by com-

(*Continued on Page* 174)

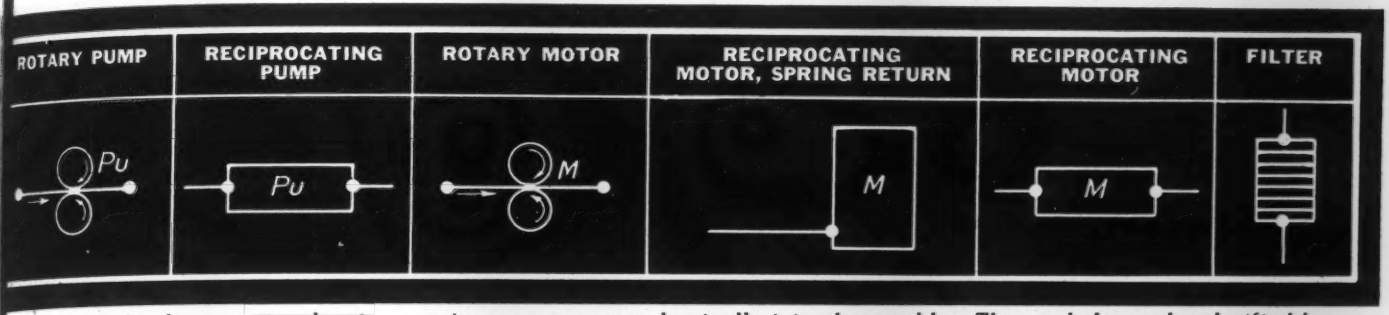


Fig. 1—Hydraulic pumps and motors are in many cases mechanically interchangeable. The symbols can be clarified by the use of control device markings—"M" to indicate motor and "Pu" to indicate pump

Standard Symbols Facilitate Circuit Design

By R. S. ELBERTY

Consulting Engineer
New Britain, Conn.

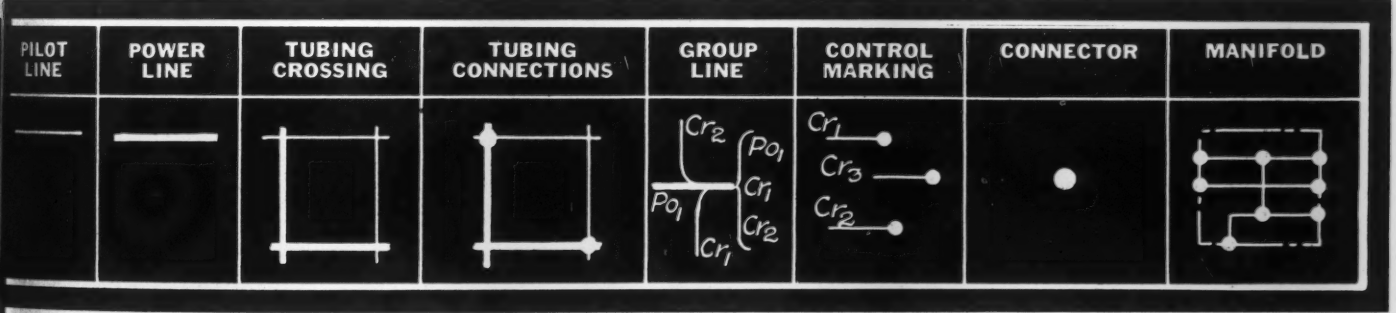


Fig. 2—Similarity between hydraulic and electrical conductors is so close that same symbols can be used on control diagrams

ENGINEERS have been helped in their early understanding of electricity by the use of comparisons with hydraulic mechanisms. There is a great common ground covering the theory of hydraulics and electricity and many electrical terms are derived from the hydraulic expressions. The problem of control brings out a considerable number of additional points in common between hydraulics and electricity, in fact this similarity accounts for much of the relative merits of the two systems. Each has its own field, the borderline cases where a choice is difficult probably not representing more than 10 per cent of the applications. Particular problems of control have been developed along independent lines and what should be an evident close relationship has suffered from these different lines of approach. Hydraulic control could benefit by borrowing from the standardized practice of electrical control engineering.

One obstacle to the complete understanding of hydraulic circuits is the lack of a standardized system for drawing hydraulic diagrams. Electrical wiring diagrams are well standardized and the electrical organizations, A.I.E.E.

Hydraulic Control Device Markings

A = Accumulator	Sl = Low Speed
BP = Balanced Pressure	M = Motor
Br = Brake	Ol = Overload
C = Check	P = Power
Cr = Control	Pu = Pump
D = Down	Pr = Pressure
E = Exhaust	R = Reverse
F = Forward	Rr = Regulator
Sf = Feed	Rf = Relief
H = Hoist	SD = Slow Down
Sh = High Speed	T = Time
I = Intensifier	Tl = Throttle
KO = Kick Off	U = Up
L = Lowering	V = Vent

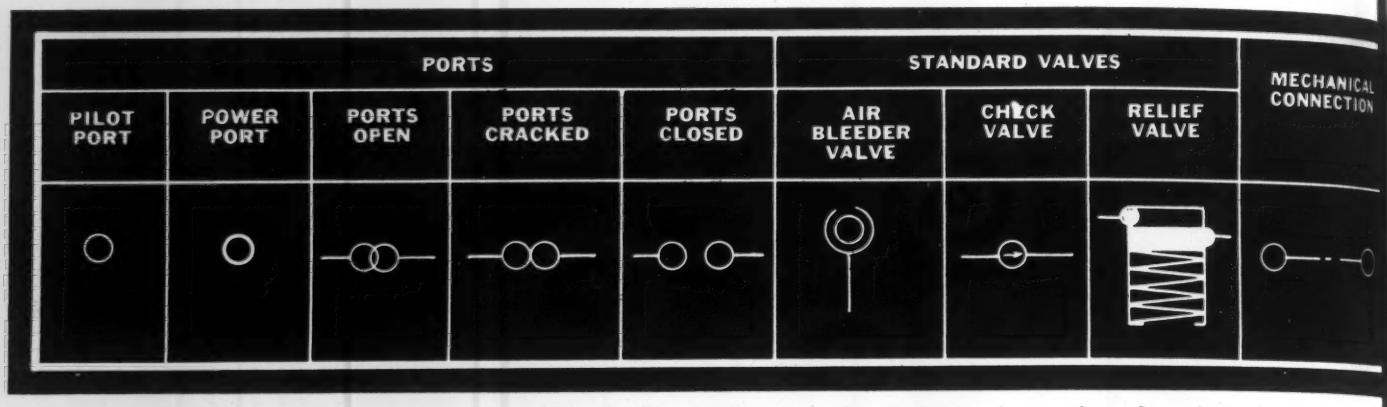
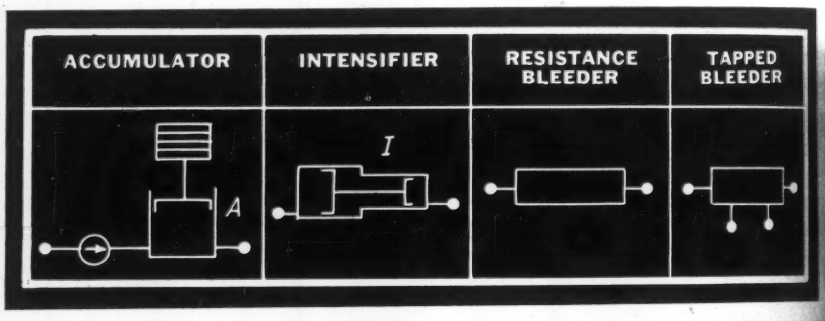


Fig. 3—Above—For the sake of clarity the number of symbols should be kept small. In the case of valves the actual structure need not be shown on the elementary control diagram

and N.E.M.A., are continually working to further this standardization. But little has been done to standardize hydraulic diagrams. Particularly needed is the hydraulic counterpart of the elementary or schematic control wiring diagram. Such a diagram shows the functional location of the control members, but their physical location is not considered in the diagram. The control members are shown by numbers or letters.

Hydraulic symbols should be simple. To arrive at a simple system, hydraulic units may be classified into five groups: Power-producing or generating units, power-conducting units, conversion units, control units, and power-actuated or motor units. All hydraulic power for machinery is obtained from a pump of one form or another. It would be difficult to derive a simple set of symbols to show the great variety of hydraulic pumps, but the gear pump symbol as commonly used should be adequate, *Fig.* 1. Hydraulic power is transmitted through tubing and a single line should be a sufficient indication of this function, *Fig.* 2. Hydraulic control units include many types of valves. A symbol for valve ports might be the best general figure and some special types could be schematically portrayed as in *Fig.* 3. Hydraulic motors may be grouped as reciprocating or rotating machines, and one general symbol for each type should be sufficient for elementary control diagrams, *Fig.* 1. Conversion units likewise may be portrayed as in *Fig.* 4. A suggested standard for hydraulic control device markings is shown in the accompanying tabulation. It employs a number of markings already used for the same function on electrical circuits.

Fig. 4—Below—Conversion devices for hydraulic control are usually employed for some type of pressure control or change. The symbols shown are partly schematic and partly derived from the equivalent electrical symbols



Considers Function Only

Once a simple system of hydraulic symbols has been devised, machine designers with electrical control experience can use this knowledge in designing hydraulic circuits. Since an "elementary hydraulic diagram" as shown in *Fig.* 5 considers function only, this should be the first consideration in the design of any control. After the control has been designed for functional requirements, then a "machine hydraulic diagram" can be

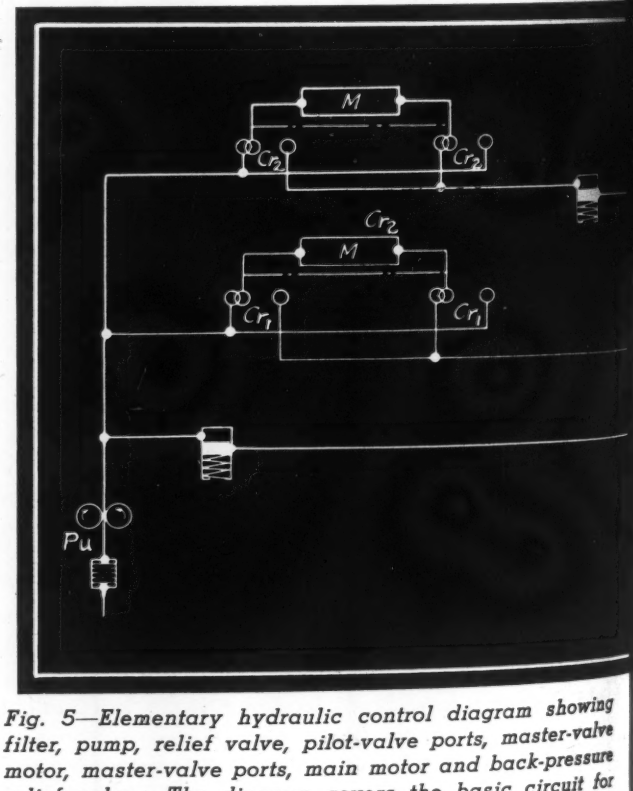


Fig. 5—Elementary hydraulic control diagram showing filter, pump, relief valve, pilot-valve ports, master-valve motor, master-valve ports, main motor and back-pressure relief valve. The diagram covers the basic circuit for hydraulic reciprocations in which the reciprocating member operates a pilot valve to cause reversal

designed to show the functional and physical relationships of each control member.

For the sake of clarity the method used in preparing these diagrams should be standardized, and here again some of the methods used on electric controller diagrams may be employed. These rules for the elementary hydraulic diagram might be stated as follows:

1. Standardized symbols and markings should be employed
2. Every item required by the control and machine should be shown on the diagram
3. Drawings should not be crowded
4. Power units should be shown at the top of the page
5. From left to right the control items should be shown as (a) pressure line, (b) control ports and operated equipment, and (c) exhaust line.

The complete hydraulic control can now be designed, but the elementary diagram should be carefully checked to determine that:

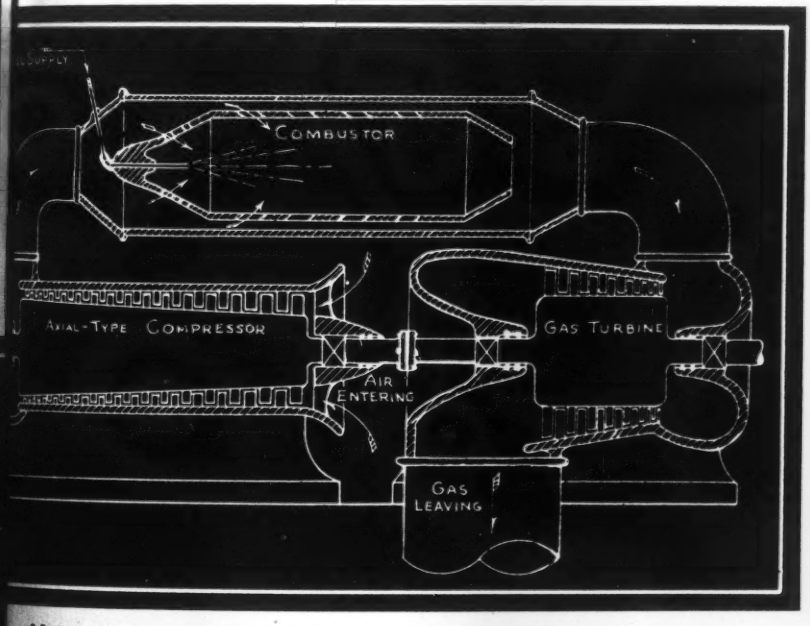
1. All the required functions are furnished
2. There are no unwanted functions.

This is a responsibility that must fall on the machine designer since it is he who best knows the exact requirements of his machine. The fundamental problem of control is the same; hydraulic, electric or pneumatic controls are very much alike from the functional viewpoint. Therefore, the diagrams should be drawn as much alike as possible. The problem is primarily one of control and must be settled by the machine designer first before it is submitted to the control engineers. To make it easier to do a better job, the various types of control diagrams should be standardized wherever possible.

What's the Future of the Gas Turbine?

By F. K. Fischer and C. A. Meyer

Westinghouse Electric & Mfg. Co.



Major elements of the simple open-cycle gas turbine are the compressor, combustor, and gas turbine itself. Also necessary is a starting motor

TO A LARGE degree the future application of the gas turbine depends upon developments in the field of metallurgy, aerodynamics, combustion and heat exchange. Present knowledge in these fields permits building and operating simple gas turbines for certain purposes, experience with some of which has been successful and encouraging. In the postwar period, industry will benefit from developments, now being engineered for national defense, which will accelerate the application of gas turbines to new and larger fields. Future applications range from electric power generation to power plants for propelling airplanes, trains and ships.

The fundamental directness of the gas-turbine power cycle, in which all the hot gases of combustion are led straight to the turbine, has intrigued engineers for years. Progress toward a practical gas-turbine power unit has been delayed because the thermal efficiency required to make it competitive with the highly developed steam cycle required: (*a*) Operation above 1000 degrees Fahr., (*b*) a highly efficient compressor, and (*c*) a highly efficient turbine. Two industries recently have made important contributions to help solve these problems. Metallurgists, in developing material for superchargers have produced alloys that are expected to withstand at least 1200 degrees Fahr. continuous service at the low operating pressures encountered in gas turbine work. Also, aviation and wind tunnel research conducted on airplane wings have contributed fundamental aerodynamic data on which high-efficiency compressor designs are based. Research in these two industries plus the accumulated steam experience of many years has made possible the necessary high-efficiency turbine and compressor elements and solved many of the mechanical problems involved in gas turbines.

The open-cycle combustion gas turbine eliminates a big and expensive step in providing power to drive machinery. In its power cycle, all the hot gases of combustion go straight to the turbine, thus eliminating the steam boiler. By contrast, in the highly developed steam cycle the energy in the fuel must first of all be converted into steam, in the boiler, before expending its energy in the turbine. In the combustion gas-turbine system of power generation there are two basic cycles—the open cycle for moderate capacities and the closed cycle for ex-

tremely large units.

Employing the simplest power cycle known the gas turbine consists of three major elements—a compressor, a combustor and a gas turbine, as shown schematically in the accompanying figure. The gas turbine resembles the straight reaction, noncondensing steam turbine, but the blades look more like airfoil sections than reaction steam-turbine blades, due to the small pressure drop and large gas volume involved. The compressor also resembles a straight reaction turbine, with the gas to be compressed passing axially through the compressor. Action of the blades in the axial-flow compressor is the reverse of the action of expansion in a reaction turbine. The combustor is the burner in which the chemical energy of the fuel oil is converted into heat energy, by burning the fuel with sufficient excess air to obtain the desired temperature. The hot product of combustion is the gas, which expands to a lower pressure and temperature in the turbine, converting some of its heat energy into mechanical energy at the turbine shaft. The combustor is relatively small since its rate of heat release is many times that of the conventional steam boiler which, in addition to burning fuel, must transfer the heat through tube walls to generate steam.

In its basic form the combustion gas-turbine cycle comprises the three major elements previously mentioned, plus a generator or shaft for transmitting the useful power output, and a means of starting. This simple arrangement is called the open-cycle system. To start a combustion gas turbine some external means, such as a motor, is required because the air for combustion is supplied to the combustor by the compressor. When the unit is in operation the energy to drive the compressor comes from the turbine.

In the simple cycle operating at 1200 degrees Fahr., the products of combustion (gas) contain some 600 per cent excess air. This gas is expanded in the turbine and exhausted to the atmosphere. Because the simple open-combustion gas cycle does not require cooling water, no steam condenser such as used in the condensing steam

Open-Cycle Gas Turbine Performances Compared*

	Simple Open Cycle	Cycle with Regeneration	Intercool and Regenerate	Reheat and Regenerate	Intercool Reheat and Regenerate
Input in Fuel	4.95	3.75	3.43	3.55	3.11
Turbine Rating	3.95	2.95	2.80	2.88	2.55
Compressor Power	2.95	1.95	1.80	1.88	1.55
Useful Output	1.00	1.00	1.00	1.00	1.00
Efficiency, %	20.2	26.6	29.2	28.1	32.2

*Assumed conditions: Turbine efficiency 85%, compressor efficiency 84%, combustor efficiency 100%, air inlet temperature 70°F, turbine inlet temperature 1200°F.

cycle is needed, and plants may be located without regard to a suitable source of cooling water.

Although the first patent was taken out over 150 years ago, early inventors were unsuccessful in getting units efficient enough to drive their own compressor. The cycle was perfectly sound, but these early inventors lacked materials to withstand the necessary high temperature as well as turbines and compressors of suitable efficiency.

Today the story is changing. Materials are capable of operating at high temperatures, the maximum temperature employed being largely a question of the useful life. For a life of relatively few hours, such as might be satisfactory for some military needs, temperatures of the order of 2000 degrees Fahr. are allowable. Heavy-duty or long-life applications are limited to much lower temperatures. Advances in metallurgy for the war effort undoubtedly will produce materials capable of operation at temperatures which would not have been attained for many years under normal peacetime development.

Until recently the axial-flow compressor which, although small in physical size, efficiently handles the large volumes required, was largely an unknown quantity. Today, the advancement in knowledge of proper blade shapes and research in the development of efficient airfoil sections have given the designer the necessary tools to design and build highly efficient axial-flow compressors.

In the gas-turbine cycle the useful power output is the difference between two fairly large quantities—the total turbine output and the work consumed by the compressor in compressing the air. With a system operating at a top temperature of 1200 degrees Fahr., for each useful unit of power output the turbine develops 3.95 units of which 2.95 is needed to drive the compressor. A reduction of 1 per cent in the efficiency of each of these elements reduces the useful output by 7 per cent.

How Efficiency Can Be Improved

Efficiency of the simple open gas cycle is low unless extremely high temperatures are used. However, there are three practical ways of greatly improving the cycle efficiency: Regenerating, intercooling and reheating. The regenerating gas cycle is a cycle in which a heat exchanger (regenerator) transfers some of the heat from the relatively hot exhaust gases leaving the turbine to the air before it enters the combustor. The amount of heat obtained from the exhaust gas depends on the size of the heat exchanger, this being an economic problem in which gain in efficiency is balanced against cost of heat-exchanger surface. Calculations indicate that the economic size of the heat exchanger will limit the regenerating cycle, at 1200 degrees Fahr. inlet temperature, to approximately 75 per cent recovery of the heat available from the turbine exhaust gases.

Efficiency is further improved when intercooling is added to regeneration. As the name implies, intercooling removes the heat of compression from the air passing through the compressor, the compressor work being reduced because the colder air has smaller volume. Other conditions remaining the same, one stage of intercooling will reduce the compressor work by some 15 per cent. This increases the portion of the turbine capacity available as useful output and improves the cycle efficiency. A large number of intercoolers is ideal but probably only a few stages will be practical.

The third method of improving efficiency, reheating, consists of adding heat to the gas as it passes through the turbine. Although the principle is the same as the reheat cycle used in many steam plants, in practice it will bear little resemblance. Reheating in the gas turbine will consist of burning fuel directly in the gas (which is approximately 85 per cent air) passing through the turbine. Here again, the practical number of reheats is limited.

Different cycle arrangements are compared in the accompanying table on the basis of the power requirements of each major element, with generator capacity unity.

Twin Cams Provide Versatility

By W. B. Gorr
Skinner Engine Co.

TO MEET the urgent need for propulsion machinery requiring a high degree of maneuverability and dependability, extreme overload capacities and permanently maintained economy, a unique poppet-valve gear control system is utilized in the marine engine illustrated in *Fig.* 1. This engine operates on the simple unaflow condensing cycle, each cylinder taking steam at full throttle pressure twice per revolution and exhausting directly to the condenser.

Admission valves are of the expansion-compensating, double-seat poppet type, designed for permanent steam-tightness. To operate them efficiently a valve gear of the rotative type was developed, having a controllable lead and a variable cutoff. This gear admits steam to the cylinder with full pressure up to point of cutoff, allows a simple and reliable control, and insures maintenance of the original economy.

Two parallel rotating camshafts, *Fig.* 2, are employed, carrying duplicate cams, each actuating one end of a cross-rider swiveled on the tappet. The camshafts are so timed with relation to each other and so constructed that one cam serves to lift the valve and the other to close the valve; with proper orientation of the closing camshaft the cutoff may be controlled throughout a wide range.

Opposite each cylinder a set of bearings under force-feed lubrication supports the camshafts, and large covers in the front of the cam box make all cams and interior parts readily accessible.

Cams and rollers have flat, wide faces so that there is a line contact between cam and roller. Furthermore, by reason of the construction of this gear, the pressure between the roller and its cam is only one-half the amount required to lift the valve. This low pressure, together with the simple tangential form of cam and the line contact of cam and roller, produces no excessive thrust on the tappet, guide or camshaft bearing.

The cam box drive, without cover, is shown in *Fig.* 3. Driven by a roller chain

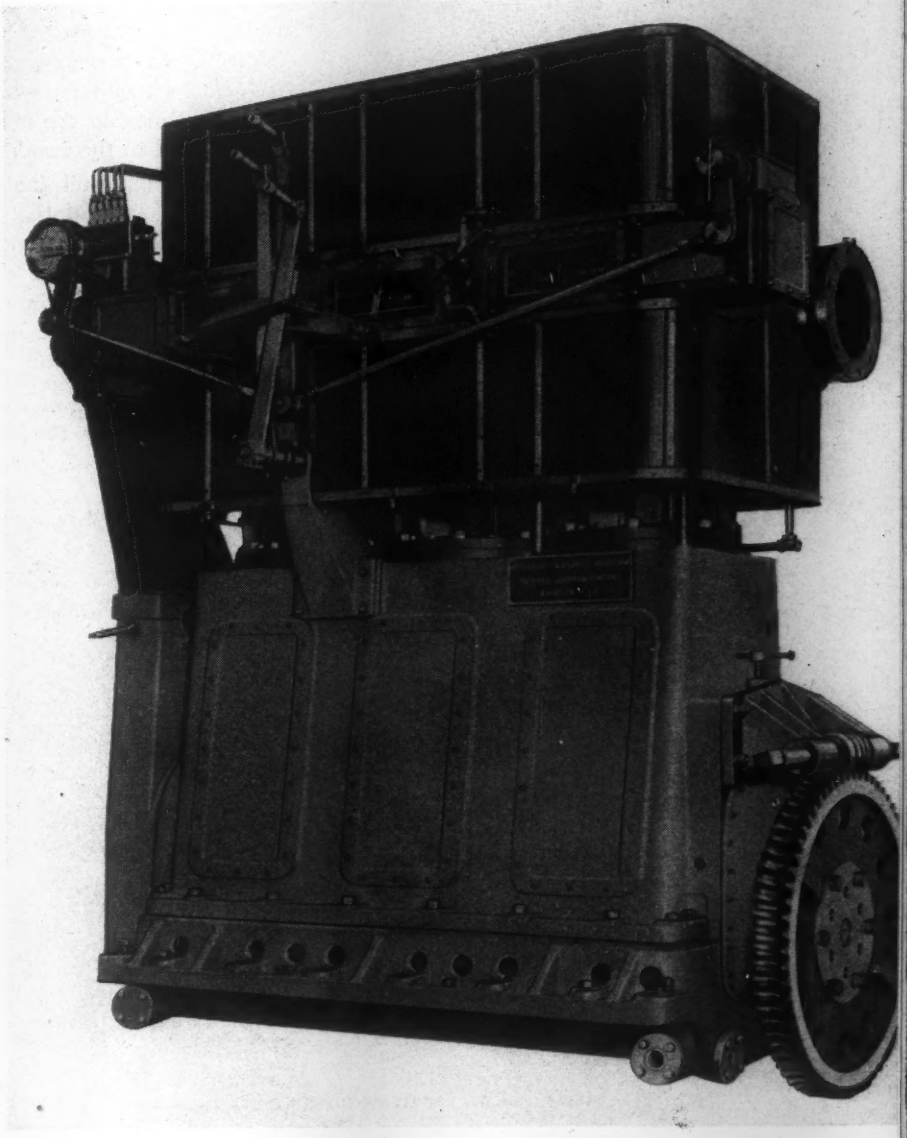


Fig. 1—Three-cylinder engine of the type installed in Army mine planters

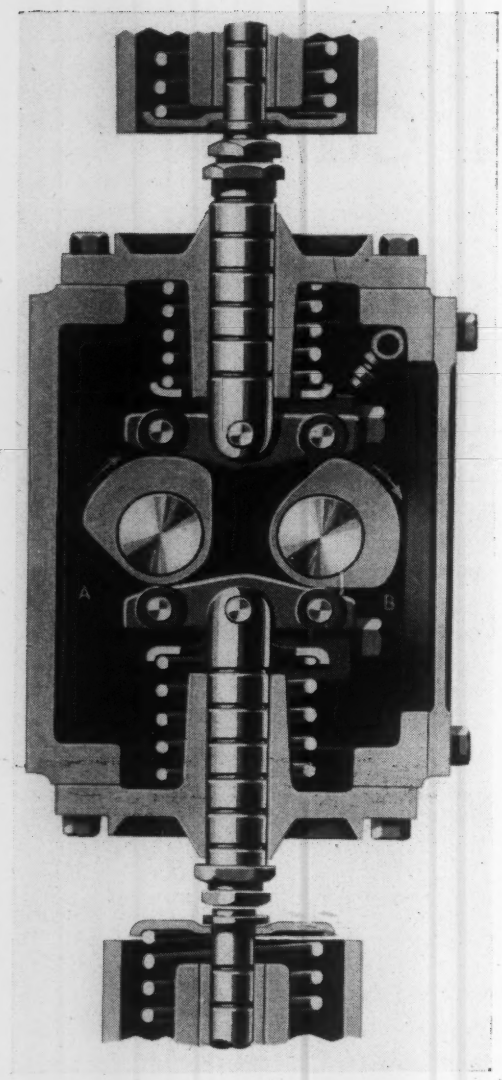


Fig. 2—Above—Parallel camshafts carry duplicate cams, each of which actuates one end of a cross-rider swiveled on the tappet

from the crankshaft, the sprocket wheel in turn drives the pinion shown within the cam box. This pinion engages two helical gears splined on the camshafts. Shifters move the helical gears lengthwise on the splined shafts, thus rotating these shafts to position the cams with respect to each other. Control levers are connected to these shifters through linkage. The position of one camshaft determines the lead or point of valve opening; the position of the other determines the cutoff or point of valve closing. When the engine is reversed, the functions of these camshafts are interchanged. The cams, rollers, pinion and helical gears are high-carbon steel, hardened and ground.

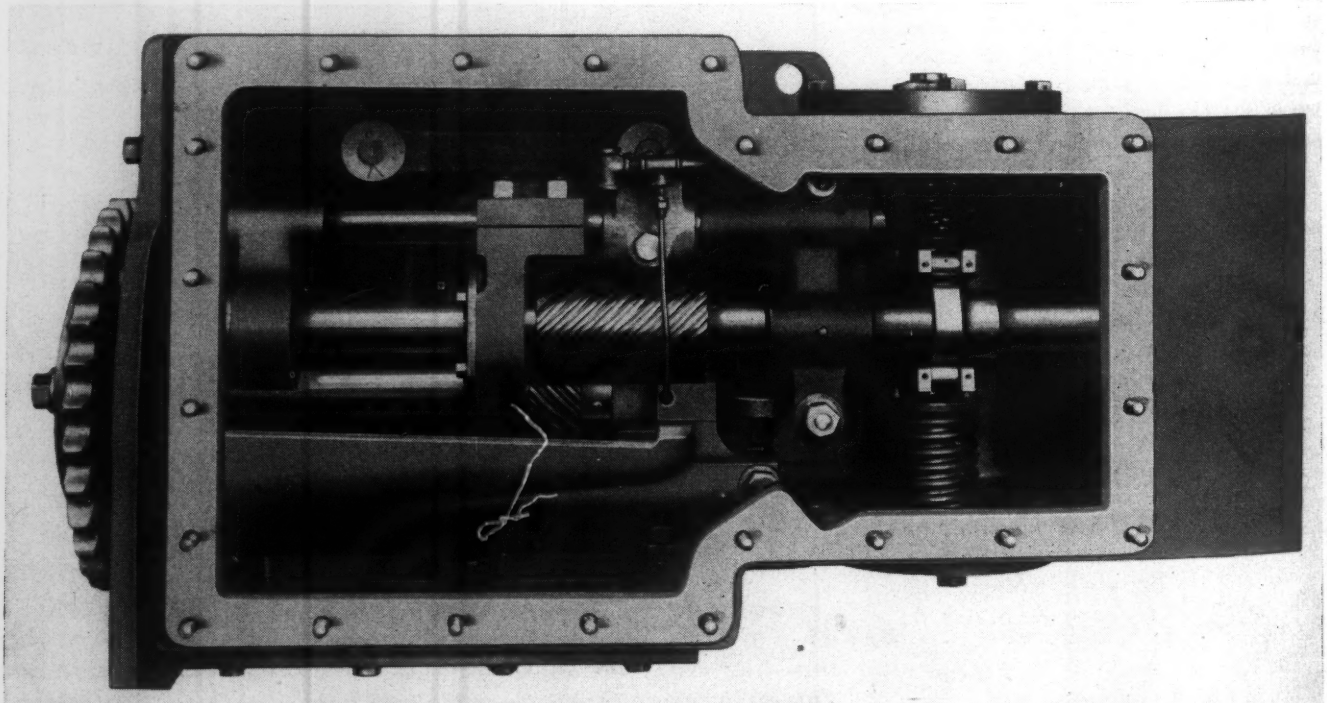
There are three main control levers, one for cutoff ahead, one for cutoff astern, and one for the balanced throttle valve. The engine may be entirely controlled with the two cutoff levers with the throttle wide open. This eliminates the throttling action employed on other types of engines, which is detrimental to steam economy. The two cutoff levers will start, stop and reverse the engine, and give practically full pressure in all cylinders for all conditions. When the levers are in the neutral position there is no movement of the steam valves, no steam is admitted to the cylinders, and thus the engine may be stopped quickly without closing the throttle.

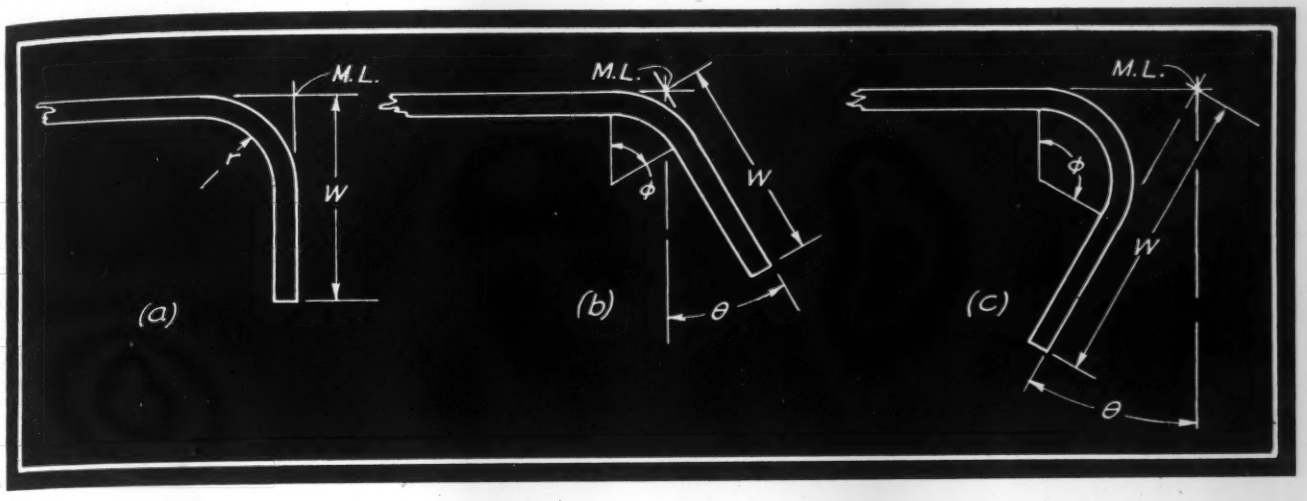
Short cutoffs are employed, namely, 10 to 15 per cent for normal operation, with up to 80 per cent cutoff available for starting, maneuvering and emergency overload conditions. This large overload capacity in the engine is transmitted directly to the propeller. This is to be compared to the 60 per cent cutoff required for normal operation of a triple-expansion engine, which results in limited overload capacity.

Cool oil under pressure of approximately forty pounds is pumped through piping to the main bearings. Thence, through drilled holes, it is conducted to the crank pins, crosshead pins and shoes, and guides.

An auxiliary oil line is carried to the cam box, delivering oil under pressure to each of the camshaft bearings, and a jet of oil is played on each pair of cams and rollers, as well as on each set of gears. As all moving parts in the engine are within an oiltight enclosure the entrance of dirt, with the subsequent contamination of the oil and consequent higher rate of bearing wear, is eliminated.

Fig. 3—Below—Cam box drive. Shifters move helical gears lengthwise to vary the relative positions of the cams





Designing Sheet-Metal Parts for Production

By Frank M. Mallett
Production Design Engineer
Columbus Plant
Curtiss-Wright Corp.

OF THE various aspects of sheet-metal production design, one of the most important and one presenting many interesting problems is the formability of the sheet-metal parts for the airplane. In discussing formability two questions are of interest: "Can the part be formed?" and "If so, can the design of the part be altered in such a way that the forming of the part will be accomplished more quickly and/or with less expensive tools?"

A few years ago the practice was to ask a man experienced in sheet-metal forming whether or not he thought the part could be made. Drawing upon his experience he gave his answer, basing it upon his memory of what had happened in the forming of similar parts in the past. But there are at least two weaknesses in this practice. In the first place, a part that appears to be similar to a remembered part actually may have some differences in detail which affect the forming. In the second place, one man's experience of this sort is difficult to impart to any one else, either for the purpose of interchange of information between two experienced men or for the purpose of training additional personnel to supply the needs of an expanded industry. Because of these weaknesses and others there is a growing tendency in the aircraft industry to seek scientific methods of determining formability which will give more precise information than is possible

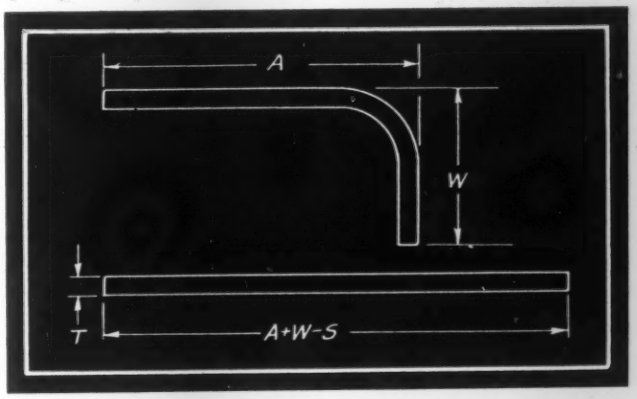


Fig. 1—Top—Illustrates notation for flanges: In open flange (b) the bevel angle θ is considered negative, while in closed flange (c), θ is considered positive

Fig. 2—Above—Lower view is blank from which angle is formed, flat pattern flange width being defined as $Y = W - S$

when only personal, individual experience and judgment are available, and which are capable of being used by any reasonably well-trained personnel that may be assigned to the problem.

The various types of forming consist of one or more of three classes of strain—elongation, compression or a combination of the two. Bending and draw are two varieties of the third class. In bending, the fibers on the outside of the bend are stretched while those on the inside are compressed. In drawing, both elongation and compression are parallel to the surface of the sheet, normal to each other. Actually this description should be applied to what might be called simplified draw which, in practice, usually is accompanied by some extra elongation in a direction at 45 degrees to that of the drawing elongation or compression.

In considering the general problem of formability of

Abstract of a paper presented at the recent national aeronautic meeting of the Society of Automotive Engineers in New York.

sheet-metal parts, there are two separate phases to the problem which may be stated in the form of questions:

1. How much elongation or compression can the metal be subjected to under various conditions?

2. How much elongation or compression does a given design call for? Alternatively, given upper limits on elongation and compression for various conditions, how can the part be designed within these limits?

Investigation already is progressing toward an answer to the first question which, however, is not easy to answer. The elongation commonly referred to in describing the

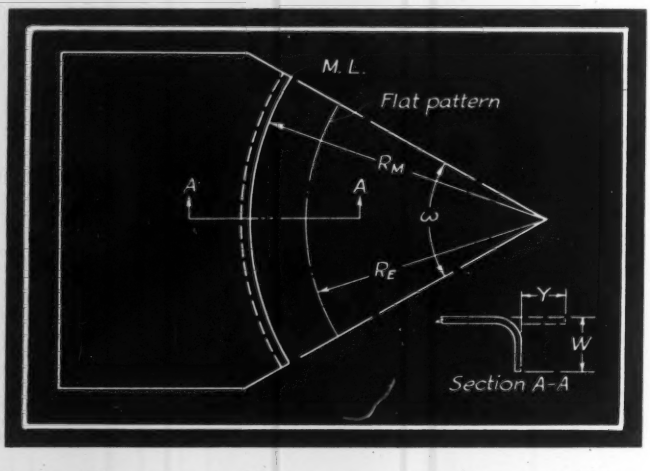


Fig. 3—Elongation in 90-degree concave flange is difference between lengths of flat pattern edge and mold line

mechanical properties of the sheet metal in question is determined on the basis of tensile coupon tests over what might be described as medium lengths. For example, the elongation given for aluminum alloys usually is specified as referring to a length of two inches. Tests have shown that much higher elongation (measured in percentage, as is customary) can be achieved over shorter lengths such as one-quarter-inch, which are met with in bending over small radii (1)* (2). It has been found also that much higher elongations are possible when accompanied by compression in a direction normal to the direction of the elongation, as in drawing (4) (5) (6). In general it may be said that the possible percentages of elongation and compression depend upon the conditions in which they are found in the formed part.

Possible Deformation Affected by Tools

The answer to the first question is affected also by the types of forming tools that are used. Some tools are not capable of stretching or shrinking the metal as much as are others. If the answers are to be used in design this may be important, because the tool needed for a certain amount of shrink, for example, may be too expensive to be justified by the size of the production run.

Problems brought out by the second basic question fall within the province of the sheet-metal group in the production design section of the engineering department. Taking the working limits previously mentioned, in whatever state of completeness or incompleteness they may be, this group must be prepared to attack the problem of applying these limits to design or, in other words, to be able to answer the second question. This problem is now being studied to some extent (12) (13) (14).

Primary purpose of this article is to present an analytical approach to the problem of designing sheet-metal parts within the working limits that have been set, with examples of the application to certain common types of forming. A limitation of the analytical method will be pointed out, and a type of experiment described which will be useful in overcoming the limitation.

The forming of concave curved flanges is an example of one of the forms in which elongation occurs. In convex curved flanges compression or shrinking occurs. Before deriving formulas for the nominal unit elongation and the nominal unit shrink it is necessary to define the terminology and notation used in discussing flanges. *Fig.* 1 illustrates the notation, in which W = flange width, r = bend radius, θ = bevel angle, and ϕ = bend angle. Note that in 90-degree flanges the bevel angle is 0, in open flanges ($\phi < 90$ degrees) it is taken as negative, while in closed flanges ($\phi > 90$ degrees) it is taken as positive.

Also to be defined is the "flat pattern flange width", denoted by Y. Width of the blank from which the simple angle, of leg widths A and W, *Fig.* 2, is formed will be less than $A + W$ by an amount S, called "setback". This setback is given by the formula

$$S = 2(r+T)\tan \tfrac{1}{2}\phi - (\pi/180)(r+KT)\phi \quad \ldots\ldots (1)$$

where T = metal thickness. The factor K usually is taken as being .446, sometimes as .5.

Definition of flat pattern flange width is then

$$Y = W - S \quad \ldots\ldots (2)$$

The term "mold line" ($M.L$) will be used to refer to the intersection of outside surfaces of a flanged part.

Nominal amount of elongation in concave flanges will now be measured. *Fig.* 3 shows a 90-degree concave flange. The mold line is assumed circular, of radius R_M. For parts where the concave mold line is not a circle arc,

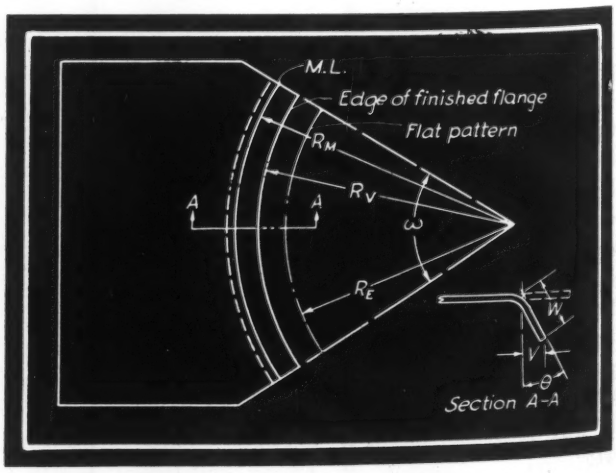


Fig. 4—For open concave flange, elongation is difference in lengths of flat pattern edge and edge of finished flange

*References in parentheses are listed at end of article.

the unit elongation at various points along it can be found by approximating the radius of curvature at these points and using it in place of R_M in the formula. From *Fig.* 3 it is obvious that the length of arc of the flat pattern edge (radius R_E) must stretch until equal to the length of arc of the mold line. Thus, if E denotes the unit elongation,

$$E=\frac{\omega R_M-\omega R_E}{\omega R_E}$$

Then, since $Y=R_M-R_E$,

$$E=\frac{Y}{R_M-Y} \quad \ldots\ldots (3)$$

also:

$$Y=\frac{E}{1+E}R_M \quad \ldots\ldots (3')$$

$$R_M=\frac{1+E}{E}Y \quad \ldots\ldots (3'')$$

An open concave flange is shown in *Fig.* 4. Here the flat pattern edge is stretched only until it equals the length of the circle arc having R_V as radius. Therefore

$$E=\frac{\omega R_V-\omega R_E}{\omega R_E}$$

From *Fig.* 4 it is seen that $R_V=R_M-V$, also $R_M=R_E+Y$, and $V=W \sin\theta$, therefore

$$E=\frac{Y-W\sin\theta}{R_M-Y} \quad \ldots\ldots (4)$$

For a closed concave flange, *Fig.* 1*c*, $R_V=R_M+V$, so Equation 4 becomes

$$E=\frac{Y+W\sin\theta}{R_M-Y} \quad \ldots\ldots (5)$$

However, if the convention on the sign of θ noted in the caption for *Fig.* 1 is used, Equation 4 becomes identical with Equation 5. Also, Equation 3 is only a special case of Equation 5 where the sine of 0 is 0. Therefore

TABLE I

Bend Radii Values for Designing Joggles

Alloy and Treatment	Bend Angle β	b = R/T for 0<T<.102	b = R/T for .102≦T<.250
24S-O	$\beta < 60°$	1	2
24S-O	$\beta \leqq 60°$	1½	2½
24S-T	$\beta < 60°$	3	4
24S-T	$\beta \leqq 60°$	3½	5

Equation 5 is the basic equation for unit elongation in concave flanges.

This same generalization is possible for the case of shrink in convex flanges, so it is necessary here to derive only the case of the closed flange. *Fig.* 5 illustrates this case. The length of arc having radius R_E must be shrunk to the length of arc having radius R_V, so, letting C = unit shrink,

$$C=\frac{\omega R_E-\omega R_V}{\omega R_E}$$

As before $V = W \sin\theta$, $R_V=R_M-V$ and $R_E=R_M+Y$ hence

$$C=\frac{Y+W\sin\theta}{R_M+Y} \quad \ldots\ldots (6)$$

which is the basic equation for unit shrink in convex flanges.

Note that for 90-degree flanges

$$C=\frac{Y}{R_M+Y} \quad \ldots\ldots (6')$$

$$Y=\frac{C}{1-C}R_M \quad \ldots\ldots (6'')$$

The applications to design of Equations 5 and 6 are obvious. For a given maximum unit shrink or elongation there is a direct relationship given by these formulas

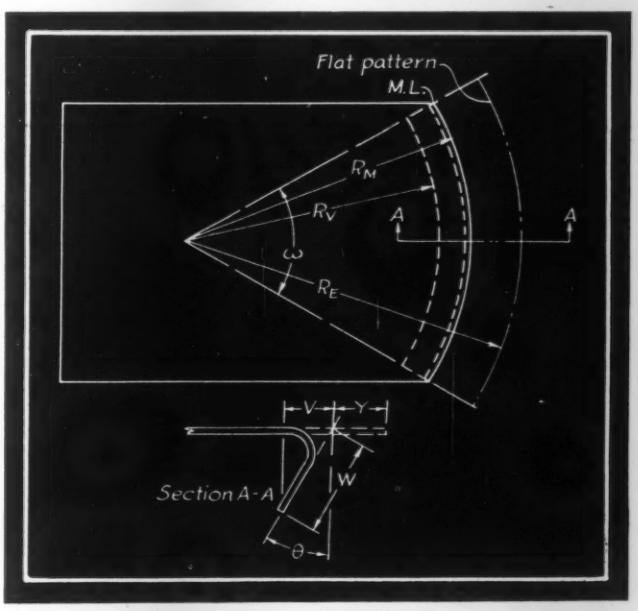


Fig. 5—Shrink in closed convex flange is difference between flat pattern edge length and that of finished flange

between mold-line radius and flange width. In the design of the part these two quantities must be adjusted so as not to violate this relationship. For example, in a 90-degree concave flanged part of .064 24S-O, with .09-inch bend radius, a maximum elongation of 14 per cent may be allowed. Then if a ⅝-inch flange is desired, the mold line radius must be 4 inches or more. If a mold line radius of 3 inches is desired, then the flange width must be ½-inch or less. Nomograms for these equations prepared by the author have proved extremely useful in the drafting room (14).

There is one limitation upon the use of these formulas for nominal shrink and elongation. When the ends of the curved flanges are free they tend to pull in, in the case

of a concave flange, as shown in *Fig.* 6. When the concave flange is contiguous with a straight flange, a small adjacent portion of the straight flange also is stretched. The effect of this is to make the actual stretch a little less than that computed, noticeably so for short lengths of flange. Corresponding effects are observed for convex flanges. The formulas are thus conservative. This is part of the general problem of local distribution of strain, which will be discussed later.

Forming of Beads for Stiffening

The formed depression used for stiffening a sheet-metal part, commonly known as a "bead", is shown in *Fig.* 7*a* in cross section normal to the lengthwise axis. One end is shown in *Fig.* 7*b* in cross section through the lengthwise axis. The terminology is: R_1 = internal radius, R_2 = edge radius, R_3 = end radius, $R_s = R_1 + R_2$, D = depth, and W = width.

Width may be computed from D and R_s, using *Fig.* 7*a*, and the right triangle whose vertices are the centers of R_1 and R_2. Using the Pythagorean theorem:

$$R_s^2 = (R_s - D)^2 + (\tfrac{1}{2}W)^2$$

$$\text{or} \quad W = 2\sqrt{2R_sD - D^2} \qquad (7)$$

Beads have various proportions, but a good standard

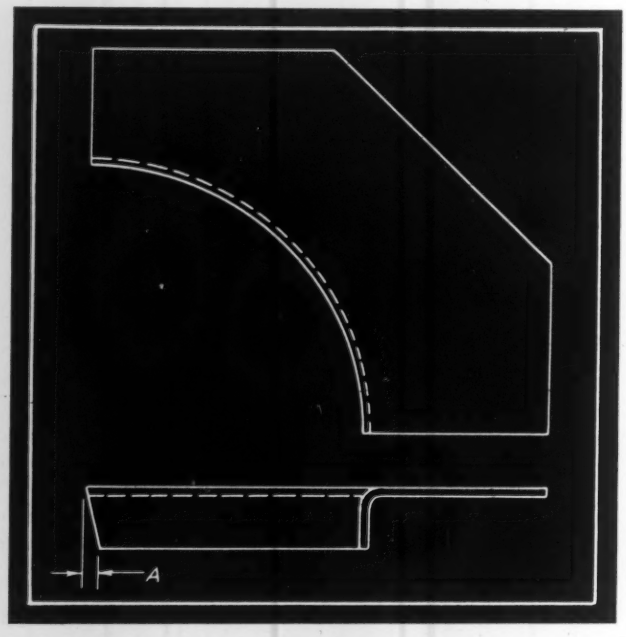


Fig. 6—Free ends of curved flanges tend to pull in, as shown at A in the case of this concave flange

shape, easily formed, is given by the following proportions:

$$R_1 = 2D,\ R_2 = 1\tfrac{1}{2}D,\ R_3 = 12D \qquad (8)$$

Using Equation 7, $W = 2\sqrt{6}D$.

Nominal elongation required to form a bead can be expressed as the unit elongation required to stretch the flat width W into the curved length of the cross section shown in *Fig.* 7*a*, which will be denoted by L.

Thus, if E represents the unit elongation,

$$E = \frac{L - W}{W} \qquad (9)$$

For the sake of simplicity, measure L along the center of metal thickness, accepting the slight error introduced by not using the neutral axis. In *Fig.* 7*a* note that the angle α is the angle of arc of each of the arcs having R_2 as a radius, and that 2α is the angle of arc for the arc having R_1 as a radius. Note also that

$$\alpha = \cos^{-1}\frac{R_s - D}{R_s} \qquad (10)$$

and is to be expressed in radians. Then

$$L = 2(R_2 + \tfrac{1}{2}T)\alpha + (R_1 - \tfrac{1}{2}T)2\alpha$$

$$= 2\alpha R_s \qquad (11)$$

Substituting Equations 10, 11 and 7 in 9,

$$E = \frac{R_s \cos^{-1}\dfrac{R_s - D}{R_s}}{\sqrt{2R_sD - D^2}} - \qquad (12)$$

This gives the nominal unit elongation in terms of the essential variables, the depth and the radii sum. Taking

TABLE II

Typical Values of Joggle Allowance Factor *p*

Depth Ratio $k = D/T$	24S-O $p = L/D$ for $0 < T < .102$	24S-O $p = L/D$ for $.102 \leqq T < .250$	24S-T $p = L/D$ for $0 < T < .102$	24S-T $p = L/D$ for $.102 \leqq T < .250$
.2 or less	5½	7	8½	10
.3	4½	6	7	8
.5	3½	4½	5¼	6
.7	2¾	3¾	4½	5
1	2¼	3	3¾	4¼
1.5	2	2½	3	3½
2	1¾	2	2½	3
3	1½	1¾	2	2½
4	1	1½	1¾	2¼
5	1	1¼	1½	2
6	1	1	1¼	1¾
8	1	1	1	1½
9	1	1	1	1¼
11 or more	1	1	1	1

the bead proportion suggested in Equation 8, the elongation required for this bead is a little less than 11 per cent.

Equation 12 is conservative because in practice the stretching occurs not only within the bead, but to a slight extent in the flat metal adjacent to the bead. The effect is particularly noticeable in rubber forming of beads that protrude away from the form block, and also is noticeable in punch and die forming (13). Again this is a matter of specific distribution of strain, which will be discussed later.

The ordinary flanged hole is merely a concave curved flange. However, the so-called "beaded" or "return flange" flanged holes present a different problem. The easiest way to solve it is to find from actual forming ex-

perience the diameter of the hole in the blank, D_C. Let D_F be the diameter of the formed hole, then

$$E = \frac{2\pi D_F - 2\pi D_C}{2\pi D_C}$$

$$\text{or } E = \frac{D_F}{D_C} - 1 \quad \ldots\ldots (13)$$

An application of bending which presents an object for study is the design of joggles, the basic terminology for

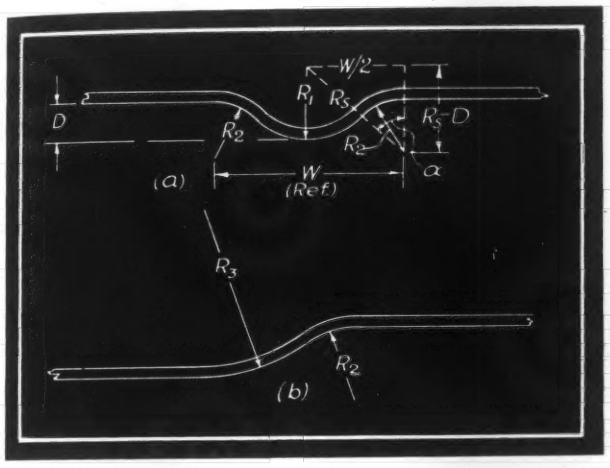


Fig. 7—Shows cross sections of a bead normal to the lengthwise axis (a) and through the lengthwise axis (b

which is illustrated in *Fig.* 8, where D = depth of joggle, R = bend radius, L = length of joggle, or "joggle allowance", and T = metal thickness.

What is usually desired in the design of joggles is as small a length as possible. This can be accomplished by making the two bends tangent to each other. In this case, R, D, and L are not independent. *Fig.* 8 helps to derive the relationship between them. The angle β is the bend angle, or angle subtended by each arc. Then

$$(2R+T)^2 = L^2 + (2R+T)^2 - 2D(2R+T) + D^2$$

$$\text{or } L^2 = 2D(2R+T) - D^2 \quad \ldots\ldots (14)$$

$$\text{Let } D = kt \text{ and } R = bT$$

$$\text{Then } L = T\sqrt{(4b+2)k - k^2} \quad \ldots\ldots (15)$$

$$\text{also } L = D\sqrt{\frac{4b+2}{k} - 1} \quad \ldots\ldots (16)$$

$$\text{Let } p = \sqrt{\frac{4b+2}{k} - 1} \quad \ldots\ldots (17)$$

$$\text{Then } L = pD$$

This proportionality factor p is important in the design of joggles. Note that it is a function of k, the ratio of depth to metal thickness, and of b, the ratio of bend radius to metal thickness. This latter ratio will be set, leaving p as a function of k. This ratio is determined for each individual case, since the depth of the desired joggle and the metal thickness necessarily must be known. p is to be considered as a minimum because any larger value, within limits, will only result in larger radii, which is acceptable.

TABLE I gives an example of how the bend radii may be set for aluminum alloy 24S.

Bend angle β is given by

$$\beta = \cos^{-1}\left(\frac{2b+1-k}{2b+1}\right) \quad \ldots\ldots (18)$$

Using the values of b in TABLE I, p is represented as a function of k by means of 8 formulas obtained by substituting in Equation 17. For example,

$$\text{When } b=1 \qquad p = \sqrt{\frac{6}{k} - 1}$$

Using the function given by Equation 17 a table can be set up for use by designers in proportioning joggles, TABLE II. However, in using the table, an exception must be made for joggles that involve other deformation beside bending, such as a joggle in a flange. In this case, p should be taken as 3, or from the table, whichever is greater. Other values of b might be chosen, resulting in different tables, while additional tables could be made for other materials.

There has been some investigation of drawing for aluminum alloys (4) (5) (6) (7). It is probable that the information supplied to the production design section by the production research group should take a direct form. The common deep-drawn shapes should be classified,

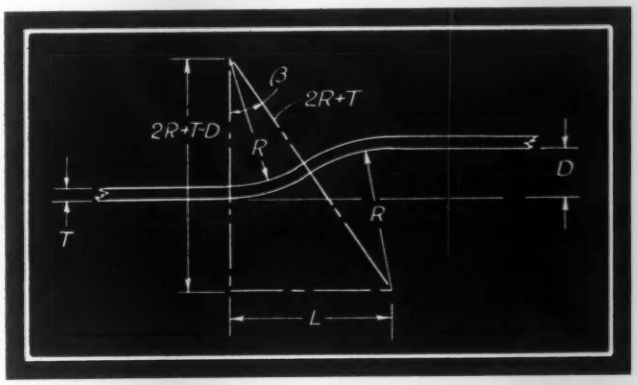


Fig. 8—Illustrates the basic terminology for joggles. For the case shown the two bends are tangent to each other

such as cylindrical, rectangular with round corners, hemispherical, etc. For each a maximum ratio of depth of draw to radius should be determined. Other ratios could be specified if redraw were permitted. The production design section could then judge the formability of various drawn parts suggested by designers and help proportion them to avoid redraw where possible.

As previously stated, refinements may be made on the use of formulas for elongation and shrink, although they already are useful, by studying the specific local distribution of strain in the various types of formed parts. The

technique for doing this already has been developed and is presented in reference (3), while use is made of it in references (1), (2), (4) and (5). It consists of applying by photography a network of lines, closely spaced, either rectangular or polar—and others could be used—to the blank which is to be formed. The strain resulting from forming can then be approximately measured by comparing the spaces between lines on the formed part with the original spacing on the blank.

When this method is applied to the forming of a bead in a flat sheet, for example, it can be determined how much elongation occurs in the metal adjacent to the bead. This not only is useful as a refinement to the formula for elongation but even more so in determining clearance distances that should be maintained between beads and other formed features of the part.

There are some types of formed parts not mentioned in this article (16). However, inasmuch as the purpose was to describe by examples a method of approach to the problem of designing sheet metal parts for formability, it is hoped that these principles will be found useful in solving other problems.

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Switching to Aircraft Engine Production

By J. G. Vincent

THERE have been, in the past, persons who held that the design and production of aircraft engines was an "art set apart" which only a few were privileged to practice. Were this the case it would, of course, have been impossible for Packard or any other automobile manufacturer to engage in such a job as the production of Rolls-Royce Merlin engines, due to the simple fact that practically all experienced aircraft engine personnel already were profitably employed by the existing aircraft engine producers. Fortunately for us the problems in design, development and production of both automobile and aircraft engines differ only in degree.

For instance, the automobile engine designer has been educated to be production-cost conscious and is possibly not so familiar with the behavior of some of the highly-stressed materials used in aircraft engine designs. Also he is not, in general, as weight-conscious as the aircraft man. The production cost and manufacturing complexities of some aircraft parts are shocking to the automobile designer, but the difference in viewpoint ends there. Manufacturing to close tolerances and the production of closely controlled finishes are nothing new to the automobile manufacturer. These things he requires, in many instances, as a matter of manufacturing economy. Accuracy in the automobile business is a necessity to interchangeability and to the avoidance of costly selective-fitting.

Aircraft engine operating parts and running clearances are in most cases no more accurate than corresponding automobile parts, although in a few cases such as splines and the balance of reciprocatnig parts, closer tolerances are dictated by higher working stresses. The finish of some aircraft parts, due to higher stresses, also is held to closer limits. However, in many cases these specified finishes have been shown to contribute nothing except to encourage faith in the product.

Regarding some of the specific problems connected with Packard's assignment, the first job was to prepare drawings from which to build the engine. It was necessary to adapt the British drawings to American nomenclature and methods. The British use third-angle projection, which means that the drawing of the left side of the engine appears at the right of the front view, so that were those not redrawn, we probably would end up with an engine running the wrong direction and probably backwards. As we had not "grown up" with this engine it was necessary to establish specifications for the finish of all parts and place those upon the drawings. In England this had not been necessary since the manufacturing personnel had been accustomed to the desired finishes over a long period of time. Sample British-made parts were checked with a profilometer and the resulting readings of finish smoothness specified on the drawings.

The redrawing occupied some 75 men for approximately four months, and 2,500 drawings were so prepared. About 50 prints of each drawing were required for estimating and manufacturing, making 125,000 blueprints issued. The output of the blueprinting department on this job was about 180,000 square feet per month—or the equivalent of a print one yard wide and 12 miles long!

From a paper presented at a recent S.A.E. meeting.

Curtailing Thermal Expansion in Design

By Frederick C. Victory
Moore Special Tool Co., Inc.

DIMENSIONAL change in machine members due to temperature variation is encountered in all types of machinery. Such instability necessarily must have its effect on the functioning of a machine unless a satisfactory method is devised either to equalize it or diminish its magnitude to negligible proportions.

As generally is known, the thermal expansion of most steels and irons amounts to about .0000062-inch per inch per degree Fahr. Where, as is often the case, temperature variation occurs over a range of ten degrees or more, the effects of thermal expansion cannot be disregarded, especially where a machine is expected to work within a tolerance of one ten-thousandth of an inch.

Heat Generating Sources

Broadly speaking, there are two sources of temperature change which affect a machine: Heat generated within the structure of the machine itself and atmospheric heat fluctuation. The former usually presents the most troublesome and least understood phase of the problem.

Obvious sources of heat generated during the operational cycle of a machine, such as motors, hydraulic pumps, etc., usually are isolated safely so as to prevent trouble from this source. Less obvious, and therefore more likely pitfalls for the designer, are sources such as rotating shafts in plain or ball bearings, gears, etc. The direct effect of such localized heating on running clearances and variations of ball bearing thrust generally are anticipated. However, the indirect effect—introduction of locational error—is not always recognized and will bear close analysis.

Three possible solutions to this in-

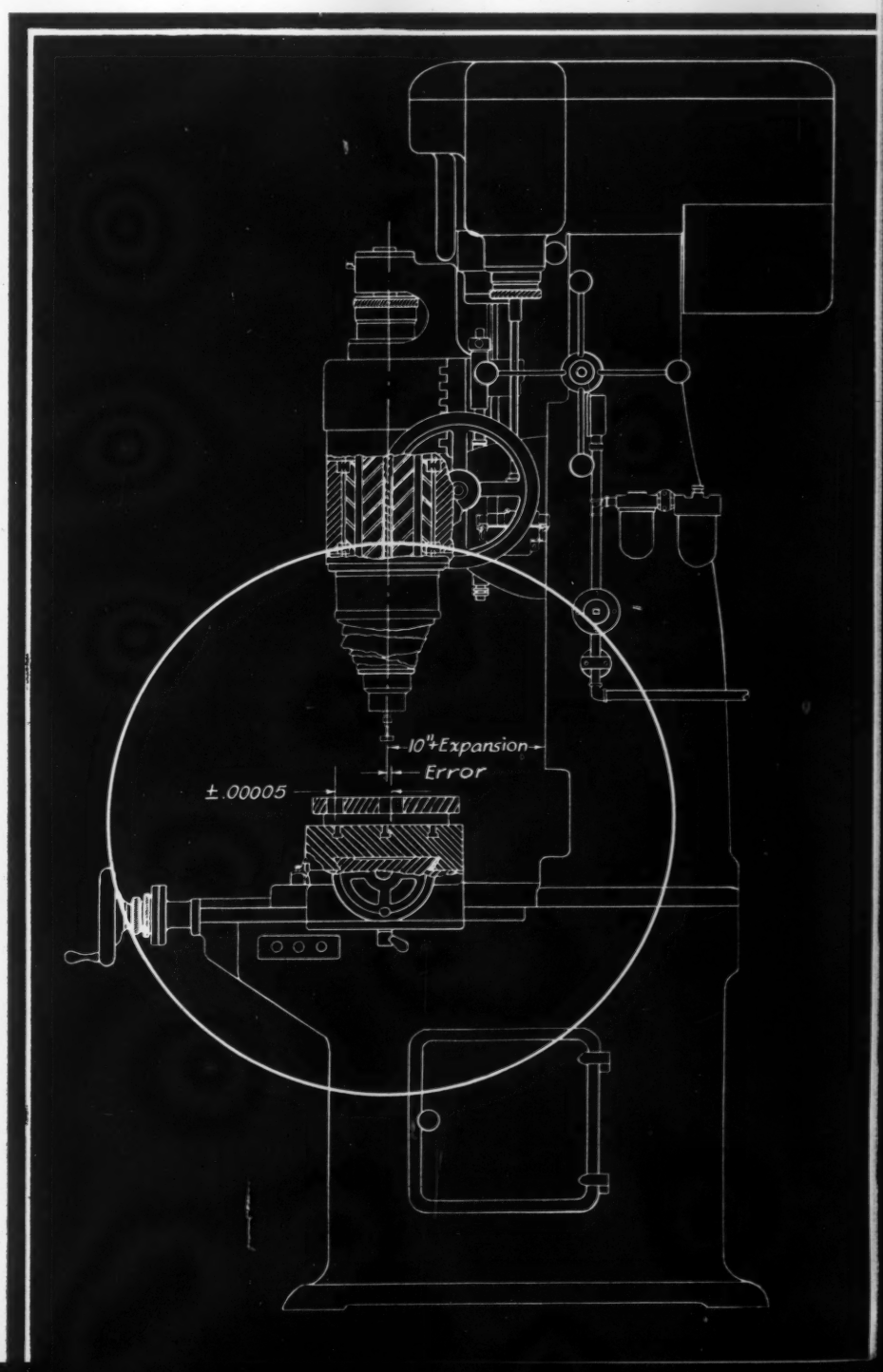


Fig. 1—Shows how thermal expansion, due to heat generated by preloaded ball bearings in the spindle of a jig grinder, can cause dimensional error between the holes being ground in a workpiece

direct result of thermal expansion present themselves:

1. The expansion may be considered as inevitable and the correction for its effects left to the skill and judgment of the machine's operator. This is only rationalization, however, and introduces the human element which never is infallible.

2. Again considering that the expansion is unavoidable, the members involved may be so designed as to be largely self-compensating. A simple application of this principle is utilized in the temperature-compensated clock. Here, to maintain the pendulum weight at a substantially constant distance from the pendulum pivot, a construction such as is indicated in *Fig.* 2 is sometimes employed. The main bar is made of steel and the auxiliary bar is of some other metal which has a higher thermal rate than steel—perhaps brass. Thus, when a rise in temperature causes the main bar to lengthen, the auxiliary bar lengthens an amount such that the distance (D) remains constant within close limits. This compensation principle, however, often involves unpredictable factors such as extra mating faces, fastenings and the attendant loss of rigidity.

3. Materials may be specified for functional members

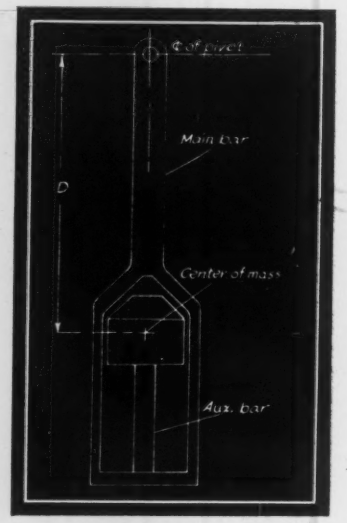


Fig. 2—To compensate for thermal expansion, clock pendulum uses materials having different expansion rates for main and auxiliary bars. Generally, this method does not prove practicable for the more complex units used in machine assemblies

in the design which have such relatively low indices of thermal expansion as to make movement from temperature change negligible over reasonable distances. This procedure provided the ultimately successful solution employed by the Moore Special Tool Company in designing the jig grinder illustrated in *Fig.* 1.

It is necessary in the operation of this machine to be able to move the work table to any desired position in a horizontal plane relative to the vertical grinding spindle. Utilizing the rectangular coordinate system of location it must be possible to locate and grind any number of holes in the work piece in precise relationship to each other and to any reference point on the work piece. Since the time required for grinding the average hole is approximately one hour, it readily will be seen that where several holes must be ground in one setting, the elapsed time may extend over two working days.

In the experimental model of the jig grinder progressive errors were noted in the hole location for this type of job. At first it was assumed that since the main spindle ran at a comparatively low speed, it would not generate enough heat to affect the housing materially. Investigation, however, proved that this was not the case. What actually occurred was a slow progressive movement of the spindle outward from its supporting column relative to the work table. This movement resulted from the linear expansion of the gray iron casting which formed the body of the housing and was due to the slight amount of heat developed by two large preloaded ball bearings mounted within it.

Ten-Degree Temperature Rise Effected

A careful check showed that, from room temperature at the time the machine was started, the outboard end of this spindle housing containing the bearings slowly warmed up to a maximum of about ten degrees above room temperature. A large proportion of this heat was radiated to the surrounding air, but the 10-inch long section serving to connect the bearing pockets with the column mounting face also was affected by direct conduction. This section exhibited a mean temperature rise of about six degrees which, multiplied by the .0000062-inch constant of linear expansion, produced a movement of the spindle of approximately .000036-inch per inch, or a total of nearly .0004-inch.

Preliminary attempts to overcome this difficulty involved the use of a thermostatically controlled electric heating element. This device was intended to maintain a constant temperature in the housing somewhat above the maximum obtained during operation. The heating element was arranged to cut in whenever the spindle was stopped long enough to allow a decrease in the heat generated by its bearings. This was an improvement but not the complete answer to the problem.

The third solution discussed in the analysis was then proposed and resulted in the development of a spindle housing of somewhat different section to be cast of Invar iron. This alloy, a special 36 per cent nickel cast iron, fulfilled the requirements, i.e., it possessed the very low index of thermal expansion of $.62 \times 10^{-6}$—approximately one-tenth that of ordinary gray iron.

Invar cast iron, in order to attain its optimum characteristics of dimensional stability, must contain a closely controlled nickel content. A variation of 1 or 2 per cent either way may reduce its thermal-index ratio to gray iron by 20 to 25 per cent, thereby decreasing its value in this respect.

In commercial castings of this material the theoretically low expansion rate could not be attained, but a consistent index of 1.5×10^{-6} or .0000015-inch per inch per degree Fahr. was noted. Tests conducted on the improved model proved that the redesign had reduced the temperature-induced error to a negligible minimum.

Design plays an important part in curtailing dimensional instability. Whenever possible, the mass should be symmetrically distributed. Highly critical members directly affecting accuracy, such as leadscrews, end measures, etc., should be enclosed within the structure of the machine itself. This will, to a great extent, tend to make any dimensional change proportional throughout the machine, and by so doing effectively reduce the possibility of appreciable error.

Choosing the Right Material

Part VI—Ability To Be Processed

By H. W. Gillett
War Metallurgy Committee

THE design engineer is directly concerned with the properties of the finished part, and his specifications must be so written that the desired properties are, and the necessary quality is, secured. It is equally necessary that the material be so chosen that processing from the raw material to the finished part is feasible and that quantity production may be reached.

Foremost among the processing requirements comes machinability. The prosaic limitations set by the rate at which the machine shop can turn out the parts hold the designer to moderate strength levels when he otherwise might use much stronger materials to improve his strength-weight ratios. Even in so important a material as armor plate for tanks, it is good sense to keep the hardness down to where it can just be reasonably well machined rather than to push the hardness up to where the armor might be a trace better.

That machinability holds the strength of many parts down to a mediocre level, on the basis of static strength, is not altogether unfortunate since, in notched fatigue—as *Fig.* 12* clearly indicates—the high static strength is illusory. Extreme care is necessary to avoid stress raisers in steels of difficult machinability that are to be used under repeated stress.

This article continues the series of abstracts from a War Metallurgy Committee report which began in the December issue.

*Part II, January issue, Page 130.

[1] Woldman, H. A.—"Relation Between Microstructure and Machinability for Alloy Gear Steels", *Iron Age*, Vol. 147, June 19, 1941.

Machinability is a function of the structure of steel and in the ordinary steels that can be considered as alternatives, the structure is determined by the heat-treatment, not the composition.

Machinability

What was unmachinable yesterday is machinable today, due to improvements in tool materials, machine tools and machine shop technique, and the range of grindable materials likewise has been greatly increased by improvements in the technique of grinding. Cost saving and increased production are such determining factors that ease of machining is a most important attribute in a metallic material of construction.

Defining "ease of machining" is difficult, because it means different things to different people. One man may appraise it on the basis of energy required to remove a given weight of chips, another on the basis of tool wear, and another on the basis of the smoothness of finish. Whatever the basis, different materials or different structures produced in steel by heat treatment are not necessarily in the same order for different machining operations, such as turning, milling, broaching, etc.

Truly precise and quantitative evaluation of fine-haired

Fig. 35—High speed photographs of cutting action of planer tools on mild steel (at left) and cast iron (at right). Transverse lines on material are spaced 1/32-inch apart

—Photos, Courtesy General Electric Co.

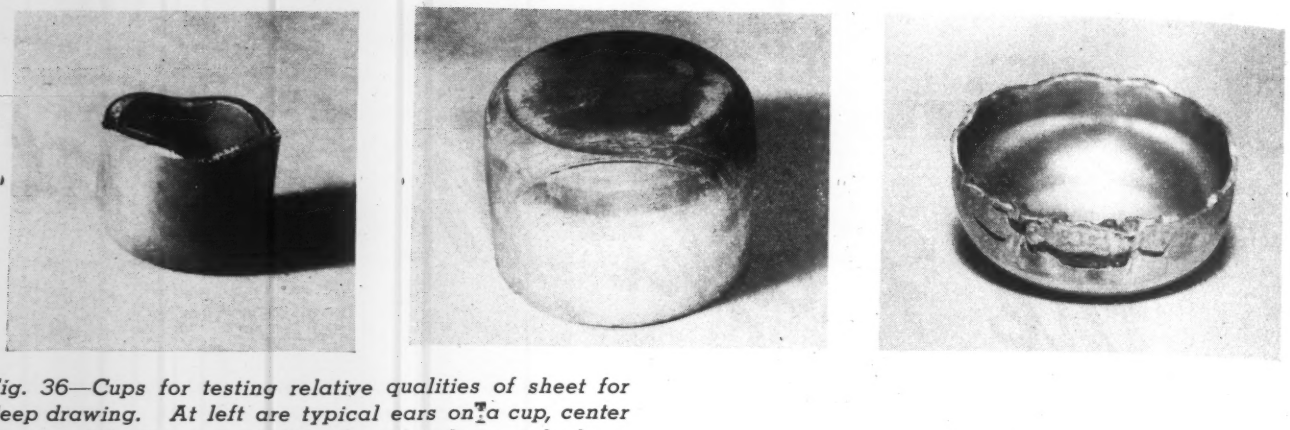


Fig. 36—Cups for testing relative qualities of sheet for deep drawing. At left are typical ears on a cup, center shows a defective cup resulting from deeply scratched raw material and right indicates a failure in a cup drawn from piped steel

differences in machinability may be time consuming and costly. Proving the value of a particular composition or heat treatment for a new high-speed tool steel or the evaluation of a new cemented-carbide tool may demand making tons of chips under the most carefully controlled conditions. Fortunately, useful information on machinability is not as difficult or costly.

For comparison of easily machined materials cold-drawn S.A.E. 1112 bessemer screw stock usually is taken as the base line reference material, and its machinability rated at 100 per cent. Annealed S.A.E. 1340 with a rating of about 50 per cent in comparison with 1112 might serve as another base. Annealed 1 per cent carbon unalloyed tool steel is taken as 100 per cent for some comparisons. When nonferrous alloys are compared, free-cutting brass, 62 copper, 34½ zinc, 3½ lead, is often taken as the base line.

Crumbly Chips Aid Machining

Without attempting to deal with fine-haired differences, it may be noted that, by nearly any criterion, commercial magnesium alloys, leaded bearing bronzes, leaded brasses, graphite-containing materials such as malleable iron, gray cast iron, graphitic steels, and high-sulphur steels such as commercial screw stock, all of which give short, crumbly chips, are readily machinable, while tough and gummy materials like pure copper, pure aluminum, nickel, and monel metal rate as machinable with difficulty, as do steels of high hardness and austenitic steels of great propensity toward work hardening.

As is clearly brought out by Ernst[2], the separation of a chip is brought about by plastic flow, followed by cleavage of the chip from the work (rupture) and perhaps by cleavage within the chip. Easy plastic flow and easy cleavage, together, mean easy machining. Easy plastic flow is naturally found in weak materials, easy cleavage in brittle ones, so both requirements are contrary to the engineering needs for strength and toughness. A compromise must be made. Stepping stones for progressive cleavage (i.e., inclusions) need to be provided that aid rupture at final breakdown but that depreciate the static load-carrying ability within the elastic range, and the fatigue resistance, as little as possible. Moreover, these inclusions should not be unduly abrasive to the cutting tool.

Adjustment of chemical composition so as to produce ready work hardening to the point of embrittlement upon the severe deformation which the chip undergoes, but not a marked embrittlement under the slight deformations permissible in service, may be used as aids to machinability.

Soft or at least relatively nonabrasive materials that can be uniformly disseminated as constituents or inclusions best fill the requirements, with graphite in cast iron and lead in brass as outstanding examples. Manganese sulphide in steels, i.e., an increased sulphur content, is a great standby.

Iron carbide (or complex carbide in alloy steels) is a brittle constituent whose distribution can be controlled by heat treatment and which, from the point of view of machining, is interspersed within the tough matrix, much as inclusions are. Its hardness and abrasive action make it oppose machinability, while its introduction of brittle stepping stones favors it. Heat treatment is therefore a potent factor in machinability and can be applied to steels pretty much irrespective of alloy content but not irrespective of a given heat and the method by which the heat is "finished"[3]. Obviously, large chunks of aluminum oxide are so abrasive to tools that care must be taken to avoid them when using aluminum to control grain size.

In low-carbon steels it is feasible to raise the phosphorus content and thus secure embrittlement of the chips without embrittling the steel. Nitrogen has a somewhat similar action. Cold drawing hardens a metal and converts a gummy one to one less gummy and also puts it part way along the road to the cracking that accompanies "over-cold-working" so that the chip tends to break up better. In *Fig.* 35 are shown high-speed photographs of the cutting action on mild steel and cast iron.

Thus cold-drawn bessemer screw stock, high in phosphorus, sulphur and nitrogen, utilizes several different mechanisms for securing machinability. Addition of a small amount of lead gives further improvement, and lead, in amounts usually under .25 per cent, can be used to increase machinability of a wide range of carbon and alloy steels with little or no harm to mechanical properties.

Other nonabrasive insoluble materials, such as silver or bismuth have a similar effect. Selenium may be used

[2] Ernst, H.—*Machining of Metals.* Published by Am. Soc. for Metals, Cleveland, Ohio, 1938.

[3] Compare Webb, L. E.—"Heat Treating N. E. Steels for Machinability", *Metal Progress,* Jan., 1943.

along with sulphur in steel, and is a well-recognized addition to stainless steels. Selenium or tellurium are likewise used in copper-base alloys. Bismuth and lead are used in aluminum-base alloys.

In steel, the grain size and the distribution of carbide affect the speed with which machining can be done and the finish produced, so that heat treatment and grain-coarsening propensities can be adjusted for the desired type of machining and final heat treatment of the rough-machined or the finished part to secure the desired mechanical properties. Discussion of this phase of the subject necessarily leads into metallurgy and the use of metallurgical terminology beyond the point of interest of most design engineers. The specific question of the machinability of the N.E. steels has been examined by Boston[4] who concludes that it "compares favorably" with that of the steels replaced.

Formability

The facility with which metals may be formed by plastic deformation, hot or cold, depends on the yield strength at that temperature, i.e., on the elastic resistance, and on the ductility or malleability after the yield strength is passed. It would, therefore, appear that most of the information necessary for evaluation would be given by a tensile test at the forming temperature.

Actually, a tensile test is inadequate for evaluation, because the deformation produced in forming is seldom by pure tension. Forming is more of a kneading than a pulling. There is more restraint upon deformation than when only free surfaces in tension are concerned, and cracking, especially edge cracking, occurs more readily. The ruling conditions under which deformation occurs in forming should be reproduced in any test for evaluation of formability.

The general behavior in hot working is usually quite well indicated—provided the time, temperature, and atmosphere of heating have been made the same as in practice—by flattening cylinders into pancakes under a power hammer and observing the edge cracking.

In hot fabrication of heavy plate, Eberle[5] appraised propensity toward hot cracking in 1½-inch plate for hot forming by heating a specimen with a 1¼-inch diameter hole in it and forcing a 3-inch diameter ball through the hole, which produced deformation akin to that necessary in the objects being produced, and noting the behavior as to cracking.

The design engineer is concerned more often with the behavior of his materials in cold forming than in hot forming. The simplest forming operation is by bending in one direction only. To appraise ability for such deformation a bend test is naturally chosen, and its severity is adjusted in accordance with the bends to be made. If it is only necessary to bend 30 degrees, the material need not be able to be bent flat upon itself. The requirements are usually phrased in terms of the angle of bend that can be endured, without cracking in the outer fibers, on bending around a pin or other form whose radius bears a definite relation to the thickness of the material to be bent. Just as sharp edges and burrs would be removed so as to decrease local stress concentration and resultant cracking in actual fabrication, so the edges of the test specimen should be smoothed. The test can be refined by measurement of elongation over different portions of the convex surface after bending, giving information analogous to that of the ductility measurements of the tension test. Magnetic powder methods could be used to make tiny cracks more evident. Rough and ready bend test equipment can be used to give about as much information as is given by a tensile test at less cost.

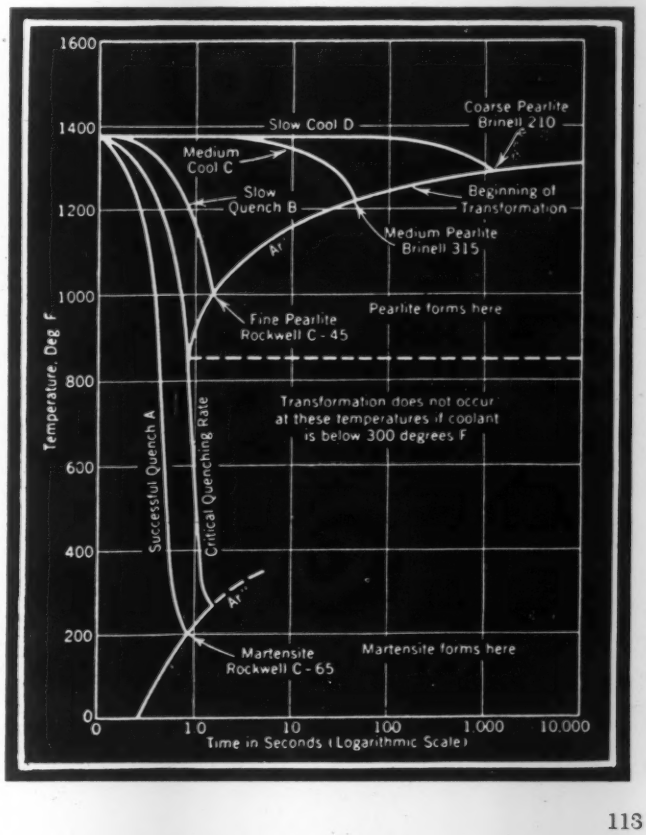
The ability of materials in thin sheet to take bends, and the radius over which they must be formed to stand bending without cracking, are evalulated by Gohn[6] who mounts V-shaped wedges with varying radii over a non-radiused V-block in a punch press and stamps the specimen into a right-angled bend, noting cracking or "orange-peeling". When only simple bending is required, accurate evaluation of difference in materials is not difficult.

Tests Become Complex

As the thickness of the material tested decreases or the deformation required becomes more complex, something better than rough and ready bend tests is needed for differentiation among materials.

Ability of material, work hardened by bending, to take further deformation, if it passes a 180 degrees single-bend test, may roughly be evaluated by repeated bending. Epstein, Nead and Halley[7] bent ⅛-inch thick sheets over a ⅛-inch diameter pin 90 degrees in one direction, then 180

Fig. 37—Rate of cooling has marked effect on weld quality



[4] Boston, O. W.—"Machinability of the National Emergency Steels", *Metal Progress*, April, 1943.

[5] Eberle, F.—"Copper-Bearing Steel for Heavy Fabrication", *Metals and Alloys*, May, 1942.

[6] Gohn, G. R.—"The Forming Properties of Some Nonferrous Sheet Metals", *Proceedings A.S.T.M.*, 36 (2), 1936.

[7] Epstein, S., J. H. Nead and J. W. Halley—"Choosing a Composition for a Low-Alloy, High-Strength Steel", A.I.M.E. *Technical Publication* No. 697.

degrees in the reverse direction, and back and forth till the specimen broke.

In deep drawing, where the metal stretches, flows under lateral compression and simultaneously withstands radial tensile strength, the combination of forces is too complex for a tensile or a bend test to tell the story. Deep-drawing operations for forming of complex shapes and twisted surfaces, like a modern automobile fender, impose such different conditions, according to the particular design, clearance between punch and die, hold-down pressure, lubrication, etc., that appraising fine-haired differences among materials by any test procedure is a task not yet satisfactorily accomplished. However, the comparative behavior of different alloys or of different heats of the same alloy can at least be approximated for some types of deep drawing by the drawing of a simple cup from a disk as shown in *Fig.* 36. In this operation the

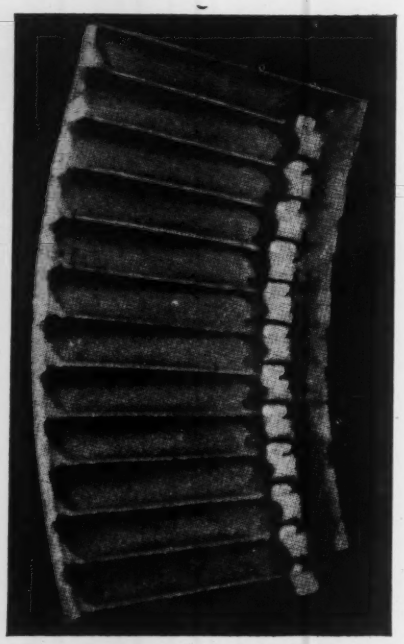


Fig. 38 — Twelve blades for a turbine rotor are cast in one piece by precision - casting method. Little finish machining is required

disk goes through the die and is thus differentiated from the familiar cupping tests, such as the Olsen and Erichsen, in which the periphery of the disk is held immobile and the center thinned down by pressure of a ball until it finally cracks, the criterion being the depth of cup that can be produced without cracking. (Orange-peeling, i.e., roughening of the surface, is, of course, also noted).

A modification in which the specimen has a central hole and the criterion is depth of cup before cracking starts at the hole might give useful information, were it not so difficult and time consuming to round and polish the edges of the hole well enough so that results will be trustworthy.

The ball and similar cupping tests that merely stretch the metal can be dismissed as adequate only for detecting gross differences, and though they often figure in specifications, producers know well that the indications are so often untrue in respect to the customer's actual fabrication needs, that they generally prefer to try to satisfy those needs rather than deliver to a cup-depth specification.

In lesser degree, the same may be true of cup-drawing tests where the disk is free to pass through the die, but the range of reliable indications seems much greater and the test thus much more useful.

With proper attention to matching the radius of the periphery of the punch, the clearance between punch and die in relation to the thickness of the stock (a very important matter in practice) and the lubrication, three features in successful deep-drawing operations in practice, cup drawing gives usable information. It was found to do so in the zinc industry long ago, as is described by Kelton and Edmunds[8] who applied it by "impact extrusion" since zinc shows better formability under rapid than under slow loading. Their criterion was the "take-in" of the metal, i.e., the diameter of the disk that will go through the die into a cup without cracking at the base or at the entrance to the die. Bartholomew[9] also finds promise in evaluation on the basis of maximum blank size. Quite sharp differentiation among materials, structures, and heats can be made by this go and no-go type of evaluation.

Since in such a cup-drawing test the total behavior is the sum of the behavior of many like wedge-shaped elements in the disk, a wedge-shaped specimen can be drawn through a die to give similar information.

Sachs, who appears to be the originator of the "wedge-draw" test, says[10] "the test gives results which agree with practical experience, but the manipulation is difficult and critical". Brewer and Rockwell[11] discuss the application of the wedge-draw test to evaluation of formability of aluminum alloy sheet for aircraft construction with illuminating detail and clearly demonstrate the greater usefulness of such a test compared with trying to interpret the result of a tension test that does not even approach having the correct stress relationships.

It seems probable that as the wedge-draw test and the actual cupping test to determine the limiting size of disk are further developed and applied, evaluation of ability for deep drawing may become more straightforward and surrounded with less mystery.

Weldability

The word "weldability" has two meanings. If the material gives off volatile gases, or forms them by reaction with the surrounding atmosphere or the welding rod or flux, the weld may be porous. The presence of alloying elements which form oxides that are not really fluxed may give difficulty from retention of the oxides in the weld. Such materials are not easily weldable. Easily weldable steels contain low carbon and gain what strength may be required by alloying below the level that gives much hardenability.

The hard, quenched, untempered structure of a hardenable steel is brittle. The mass of cold metal about the freezing metal of a weld is an effective quenching agent. Size of this mass affects the severity of the quench. Hence, a steel may be weldable, without precautions in ½-inch section, and unweldable—unless special precautions are

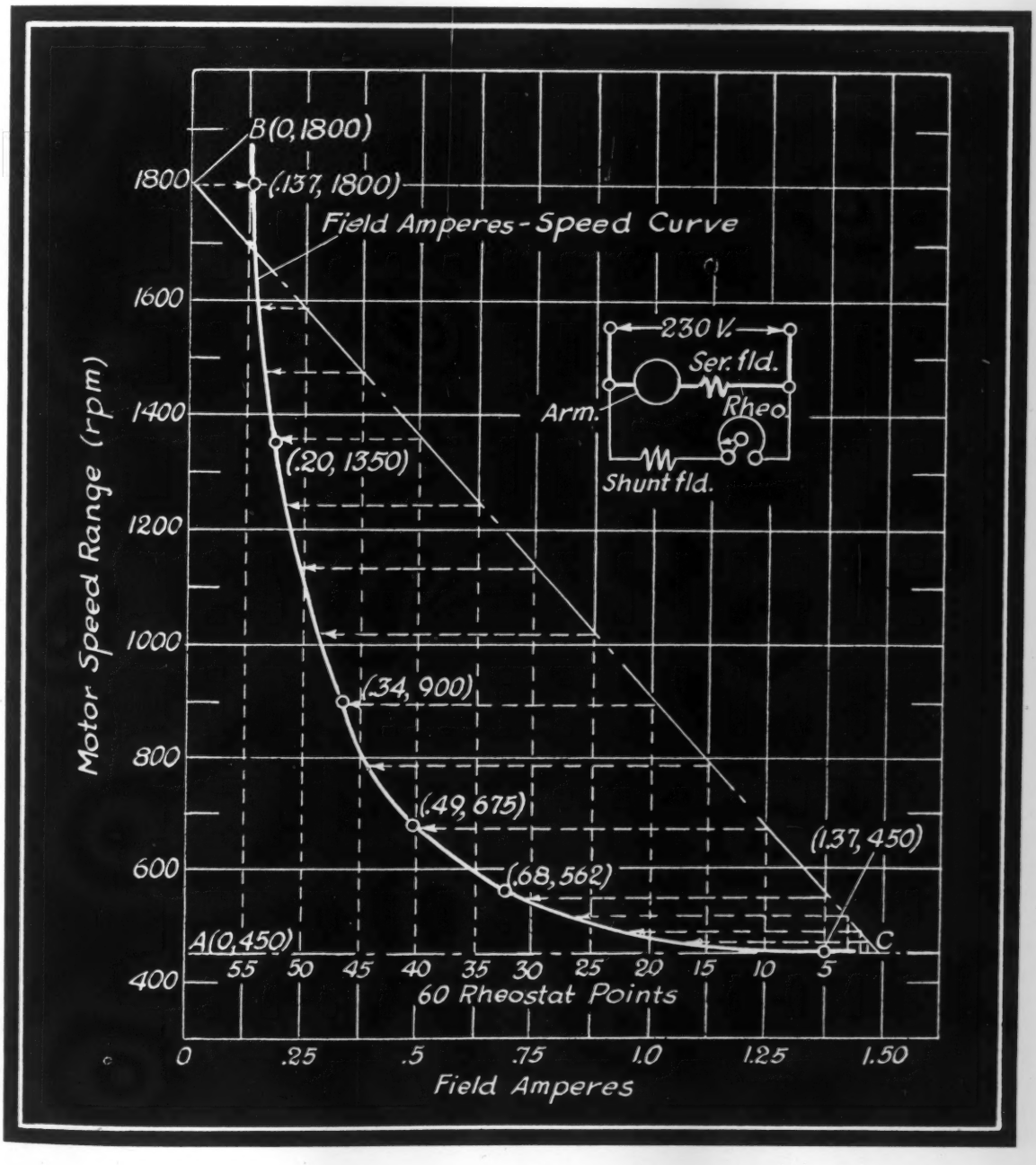
(*Continued on Page* 164)

[8] Kelton, E. H. and G. Edmunds—"Testing the Drawing Properties of Rolled Zinc Alloys", A.I.M.E. Institute of Metals Div., 1934.
[9] Bartholomew, E. L., Jr.—"Stress-Strain Measurements in the Drawing of Cylindrical Cups", *Transactions Am. Soc. Metals*, Sept., 1943, Pages 582-598. (Note discussion by R. G. Sturm, Page 595).
[10] Sachs, G. and K. L. Van Horn—*Practical Metallurgy*, Page 433.
[11] Brewer, G. A. and W. M. Rockwell: *Metal Progress*, 1942, May, June, July, August.

When Motor Speed-Change Steps Must Be Equal

By Ralph B. Immel
Control Engr., Westinghouse Electric & Mfg. Co.

OFTEN IT IS desirable to provide equal steps in speed changes for a machine. When the drive is either a direct-current shunt or compound motor, proper selection of the resistances between the field rheostat points to provide these steps may be determined readily by the graphical method presented in this discussion. The resistances necessary are obtainable from the speed curve of



the motor which is being controlled.

First, the motor field amperes *vs.* motor speed in revolutions per minute is plotted as shown. The particular application or closeness of speed adjustment will determine the number of points that should be in the rheostat. After the number of rheostat points has been selected and the desired speed range has been decided upon, the straight line *AC* is drawn parallel to the horizontal base line. The ordinate of its starting point on the zero field-current vertical axis should be the lowest speed desired. For field control only, the minimum motor speed never can be less than that at full field or with no external resistance in the shunt field circuit.

Rheostat points are laid out along the line *AC* and should be equally spaced. The highest rheostat number

TABLE I

Field Amp.	RPM	% Full Field Speed
1.37	450	100
.68	562	125
.49	675	150
.34	900	200
.2	1350	300
.137	1800	400

Shunt field resistance at 25 degrees Centigrade is 166 ohms.
Shunt field resistance at 75 degrees Centigrade is 200 ohms.

should fall on the intersection of the line *AC* with the zero field-current vertical axis. Then oblique line *BC* is drawn from the first rheostat point to the ordinate on the zero field-current vertical axis which is the highest speed desired. This highest speed, of course, should not exceed that recommended by the motor manufacturer. Next, vertical lines are drawn from each rheostat point until they intersect the oblique line *BC*. After intersection with this line, they are drawn horizontally (in either direction) until they intersect the curve of motor field amperes *vs.* motor speed. This intersection will indicate the field current for a given rheostat point.

This procedure is simply a graphical means for dividing the distance between the lowest and highest speed ordinates into equal spaces proportional to one less than the number of rheostat points. It is illustrated on previous page for a typical rheostat resistor design for a 5-horsepower, 230-volt compound-wound, direct-current motor. The field amperes *vs.* motor speed in revolutions per minute were plotted from the motor test data for the coordinates of points (.137, 1800), (.2, 1350), etc. This motor has a 4 to 1 speed range by field control and the desired operating range in this instance was from 450 to 1800 revolutions per minute. The rated load field data for the motor are shown in TABLE I.

When the field amperes for a particular rheostat point are known, the total ohms in the field circuit can be calculated. These data are tabulated in columns 1 and 4 of TABLE II. Either the hot or cold-field resistance may be used in calculating the resistance to be connected to the rheostat face-plate. For this example, the cold-field resistance value has been used as it provides some practical advantages. The shunt field can reach its maximum temperature rise only when the motor is operated at the lowest speed and when there is zero external resistance in the field circuit. When the motor is operated at a higher speed, the field current is much less than that at full field and the higher speed provides additional cooling. When a motor with a 3 to 1 or 4 to 1 speed range is required, it is likely that the motor will be operated either all or part of the time at a speed above the minimum value. However, it is well to check the particular application. With a rheostat designed on the basis of the cold field (25 degrees Cent.) it is always possible to attain the maximum speed when first starting. This is not true of a rheostat which has been designed on the basis of a hot-field resistance value as there will be insufficient external resistance when the field is cold to reduce the field current to a value that corresponds with the maximum speed. The maximum speed for a hot-field rheostat design can be attained only when the field is at its maximum temperature.

Many direct-current motors of this type are designed for a shunt-field temperature rise of 50 degrees Cent. This means that the cold-field resistance is approximately only 85 per cent of the hot-field resistance. The change in resistance can be calculated from the temperature coefficient of resistance formula for copper which is

$$\frac{R_{cold}}{R_{hot}}=\frac{R_{25°}}{R_{75°}}=\frac{234.5°+25}{234.5°+75°}=\frac{259.5°}{309.5°}=84 \text{ per cent}$$

As shown in column 4 of TABLE II the resistance between points 1 and 2 is 43 ohms which is the difference between the total field-circuit resistance and the cold-field resistance. For many applications it is satisfactory to assume that the motor field amperes *vs.* motor speed

TABLE II

1 Rheostat Point	2 Field Amperes	3 Total Ohms	4 Rheostat Ohms
1	1.37	166	0
2	1.1	209	43
3	.95	242	76
4	.85	270	104
5	.75	306	140
10	.5	460	294
15	.4	575	409
20	.34	678	512
25	.29	792	626
30	.25	920	754
40	.2	1150	984
50	.156	1480	1314
60	.137	1660	1494

in the R.P.M. curve is a straight line between five or ten rheostat points. This can be verified by checking the curve between rheostat points 40 to 50. For calculating the resistance between each point in this region, the total resistance between points 40 and 50 should be divided by 10. When more precise speed control is required, the resistance should be calculated individually for each point. For this particular example the field amperes were found graphically at the upper end for every tenth point. The resistance between any two points or any two groups of points can be found by subtracting the higher *total* rheostat resistance value from that for the lower numbered point or group of points.

After the resistance between each point has been calculated, resistor tubes or tapped sections of resistor elements may be connected to the rheostat faceplate in accordance with the ohmic values that were calculated for the various points. The field amperes listed in Column 2 of TABLE II should be used in selecting resistor elements with the proper current (or wattage) capacity.

Break from Tradition Offers Better Chance for Reconversion

ABILITY of machine building companies to convert to the production of equipment entirely foreign to their standard lines has been clearly proved during the war. Amazing changeovers have been effected. Innumerable companies throughout the country now are turning out war equipment of one type or another in a way that would have been considered impossible three years ago.

At the start even the automobile concerns—accustomed as they were to changes in models and in methods—were averse to tackling some of the war jobs that seemed to be heading their way. As the need for gigantic production of fighting equipment became more acute, however, these same companies turned to with a will and disproved the contention that only specialists were capable of taking care of certain classes of production.

The same is true of many companies now producing ships by the score. Some of these concerns are located hundreds of miles away from the sea coasts and the Great Lakes. Yet many of the vitally necessary invasion craft are being manufactured far inland and moved to the ocean through rivers and other waterways.

At the other extreme, instruments of all kinds no longer are the sole concern of former instrument makers—another specialized trade. A good example of this is the production by The National Cash Register Co. of the highly complex computing gun sight used in aircraft turrets.

Does not this facility for change augur well for the war production still needed and for the success of reconversion after the war? No longer should machine building companies that have specialized in certain lines feel "wedded" to those lines forever. Traditional concepts can and will be broken. To many organizations the enforced shaking up may well prove a blessing in disguise—not only to the companies themselves but to industry and the country in general.

L. E. Jermy

Outstanding Designs - Hydr

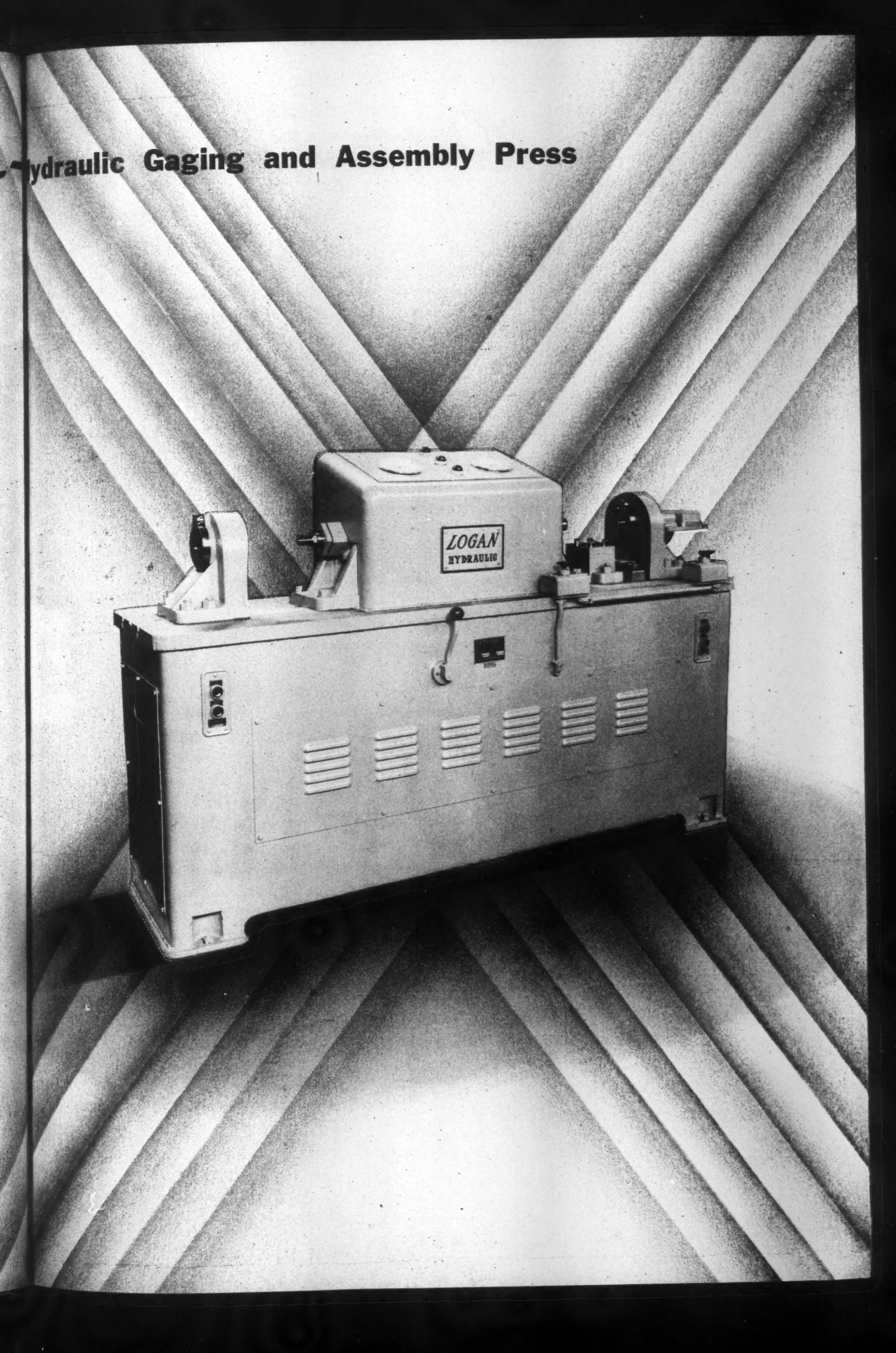
Purpose of this machine, developed by Logansport Machine Inc., is to press a splined shaft into the mating center of a disk-shaped part at an adjustable predetermined pressure and to disassemble the same unit for tear-down inspection after the green run of a completed engine. The right half of the machine is for assembling and the left half for disassembling.

Three indicating lights are provided to show the type of fit being obtained. An amber light shows that the press fit is too free, a green light indicates press fit within the prescribed limits, and the red light, indicating a fit which is too tight, is accompanied by automatic stopping of the pressing stroke of the hydraulic cylinder.

Two independent hydraulic systems are employed, each consisting of a motor-driven pump mounted on an oil reservoir, an adjustable pressure-control valve, an operating valve, and a hydraulic cylinder. The two cylinders are mounted in the center of the table top and are covered by a hood which carries the pressure gages and indicating lights. Two standard hydraulic power units, along with the operating valves, are mounted in the base of the machine.

Two adjustable snap-action type double-pole, heavy-duty pressure switches are installed near the cylinders under the hood and are actuated by the oil pressure of the assembly cylinder. These switches and a suitable contactor operate the indicating lights and stop the pressing stroke of the assembly cylinder when the press fit becomes too tight. Work-holding fixtures with interchangeable locating bushings and collars for different work pieces are provided on each end of the machine as well as interchangeable support blocks for the shaft of the unit being assembled.

Made from centrifugally cast close-grained iron, the two cylinders have bores which are honed to a mirror finish. The smooth bore of these cylinders together with the accurately fitted pistons equipped with low-friction piston rings, as well as the self-adjusting rod packing which cannot be tightened excessively, insures the low and uniform friction necessary in order to obtain the correct relationship between working oil pressure and pressing force.


ydraulic Gaging and Assembly Press
LOGAN
HYDRAULIC

Outstanding Designs

Combining power and compactness, this 40-kilowatt high-frequency generator manufactured by "S" Corrugated Quenched Gap Co. utilizes two water-cooled triodes in a grid-plate feedback oscillating circuit. Plate power is furnished from a three-phase six-tube rectifier with control and filament circuit power equally distributed over the three phases.

Employing no large moving parts, the stepless control is operated through a specially developed circuit, and feedback, tank impedance, grid resistance and power output are subject to control and adjustment. The oscillator tube filaments have individual controls while the cold-tube filament surge current is limited by a special high-reactance filament transformer. Filament voltage can be dropped well below rated value to increase the life of the tube when using only small amounts of power. A plate time-delay relay prevents application of plate voltage prematurely.

By use of an additional time-delay relay, water is allowed to flow through tube jackets for three minutes after the generator is turned off to carry away filament and grid heat. The water system is controlled automatically by a solenoid valve and complete protection against system failure or overheating is provided.

When the unit is in operation, the upper front doors are closed and only the necessary controls are available. Meters measure the filament voltage, plate and grid currents and radio frequency output. All of the fuses, relays and contactors are readily accessible for inspection or service since they are mounted directly behind the lower front doors. Top and sides of the cabinet are removable. They are, however, interlocked with the control circuit in such manner as to render the generator inoperative when top or sides are removed.

Constructed of solid maple stock, the cabinet employs a standard finish of gray lacquer which is hand rubbed to a satin gloss. All transformers are oversize with high-grade silicon steel cores. The radio frequency unit is watertight and isolated from the rest of the circuit as a safeguard against damage to other components in the event a leak develops in the water system.

An indication of the sound engineering which has developed this generator is found in its high power rating. It develops one-half kilowatts of power per cubic foot or three kilowatts per square foot of floor space.

(For new machines listing see Page 178)

1 High-Frequency Generator

Design Roundup

New Concepts in Design

THAT THE TREND toward wider use of electronics is developing despite wartime restrictions was evident in exhibits and discussions at the American Management Association's recent packaging conference and exposition in Chicago. New developments include dielectric heating for molded packages; setting of cements and glues by electronic heat; high-speed induction heating of metal as an aid to riveting, crimping, sealing of metal containers, flash soldering of seams, etc.; and dielectric heat for dehydration or sterilization of food and drug products. In a paper on the subject, V. W. Sherman, manager, industrial electronics division, Federal Telephone & Radio Corp., Newark, N. J., stated: "We need to modify our mental concept of a machine. To the old world of wheels, gears, motors and belts, we must add the power tube which is self-contained and silent, but is capable of transforming and controlling large amounts of electrical energy."

Deep Drawing Saves Material

REDESIGNED from a forging of 17S aluminum, domes for the housing of the mechanism of the Hamilton Standard Hydromatic aircraft propellers are now being produced by Worcester Pressed Steel Co., utilizing deep drawing and forming. Because 17S would not stand the repeated severe reworking, 61SO is used. By thinning the wall and stamping, savings up to 16 pounds per dome are realized and, since three and one-half million pounds of aluminum alloy have been fabricated, this has resulted in considerable cost reduction.

Heat treatment brings the ultimate tensile strength to 42,000 pounds per square inch, comparable to mild steel, and yield strength is high, 35,000 minimum. Elongation in 2 inches is 10 per cent minimum, indicating a high degree of formability and the ability to resist heat-treatment distortion. The Worcester company is heat treating this alloy to a brinell hardness of 90 through aging in Lindberg furnaces, water quenching and aging in Gehnrich ovens.

Three sizes—large, intermediate and small—are produced. The intermediate size is the most generally used and is produced from a 19¼-inch disk, .5 to .54-inch thick, weighing 15.3 pounds. The finished dome has a hemispherical bottom, 13 inches deep and 9 9/16 inches outside diameter.

Powder Metallurgy Strides Ahead

ALTHOUGH powder metallurgy has many limitations, it often can be utilized to advantage and in many cases is successfully replacing or competing with other manufacturing processes as a method for making machine parts. If a part design can be simplified sufficiently, powder metallurgy promises to do many things that more conservative designers believe are impossible for technical or economic reasons. So rapid has been the advance in technique for production of heavier pieces, that the Amplex division of Chrysler is making units in excess of 100 pounds and has an output of better than 250,000 pieces of all sizes per day. Moraine Products division of General Motors is manufacturing pole pieces for electric motors from iron powder, an application which throws the method into competition with fabricated sheet steel.

Design To Meet Obsolescence!

APPLICATION of aircraft type electrical components to machines after the war offers intriguing possibilities. Much has been done toward increasing motor power per unit of space and per unit of weight. The same is true of control items, and to some extent of power transmission devices such as reducers and couplings. It is true that in many cases these attributes were obtained at the sacrifice of other desirable characteristics, such as length of life. There are, however, definite indications that length of life in a machine is becoming less and less an important factor as the rate of obsolescence increases. For example, there is no point in the installation of power equipment good for 20 years' service in a machine which may be obsolete in ten years or less.

Nomogram Aids Thick Cylinder Calculations

By Carl P. Nachod
Nachod & United States Signal Co. Inc.

IN CYLINDERS subjected to internal pressure, principal stresses exist in three mutually perpendicular planes—tangential, radial and axial. On the assumptions that total axial deformation and axial stress both are constant at all radii (Lame's theory) the following equations for the stresses at any point can be derived:

$$s_t = \frac{pa^2}{b^2-a^2}\left(\frac{b^2}{r^2}+1\right) \quad \ldots\ldots (1)$$

$$s_r = -\frac{pa^2}{b^2-a^2}\left(\frac{b^2}{r^2}-1\right) \quad \ldots\ldots (2)$$

$$s_a = \frac{pa^2}{b^2-a^2} \quad \ldots\ldots (3)$$

where p = internal pressure, pounds per square inch; a = inside radius of cylinder, inches; b = outside radius of cylinder, inches; r = any radius lying between a and b. It will be noted that s_t and s_a are always positive, denoting tensile stress, whereas s_r is negative, denoting compressive stress.

Of these principal stresses the tangential stress, s_t, is the most severe, as Equations 1, 2 and 3 show. Further, the maximum value of s_t occurs when $r = a$. Substitution in Equation 1 gives the maximum:

$$s = p\frac{b^2+a^2}{b^2-a^2} \quad \ldots\ldots (4)$$

On the assumption that this stress is the criterion of failure (maximum normal stress theory) this formula is widely used as the basis for design of thick cylinders. To facilitate calculations the nomographic chart on Page 124 may be used, this being based on Equation 4.

To use the chart, a pair of straight lines crossing at right angles, each one of which cuts both sides of one of the right angles, is laid on the chart as shown in the example. The pair of computing secants drawn in dotted lines shows that if the outer and inner radii are 9 and 6 inches, respectively, and the internal pressure is 2000 pounds per square inch, then the maximum tangential stress is 5200 pounds per square inch.

The four scales are on two pairs of lines at right angles with a common vertex, and are rotated 45 degrees from each other. Scales p and s are proportionally graduated with the same modulus, while scales b and a are graduated proportional to the squares of the numbers. The origin of all scales is at the vertex. Either pair of numbers, a and b or p and s, may be multiplied or divided by the same constant without changing the result. If the two secants are scratched on transparent film or drawn on tracing paper, the computation is particularly fast and convenient. The chart may be used with equal facility to solve for the outside radius, assuming that the inside radius, internal pressure and working stress are known.

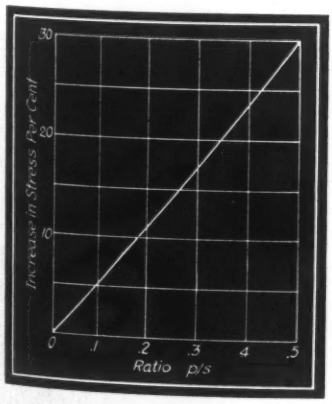
If the walls of the cylinder are thin in relation to the diameter, the following simple formula is sufficiently accurate:

$$s = \frac{pa}{t} = p\frac{a}{b-a} \quad \ldots\ldots (5)$$

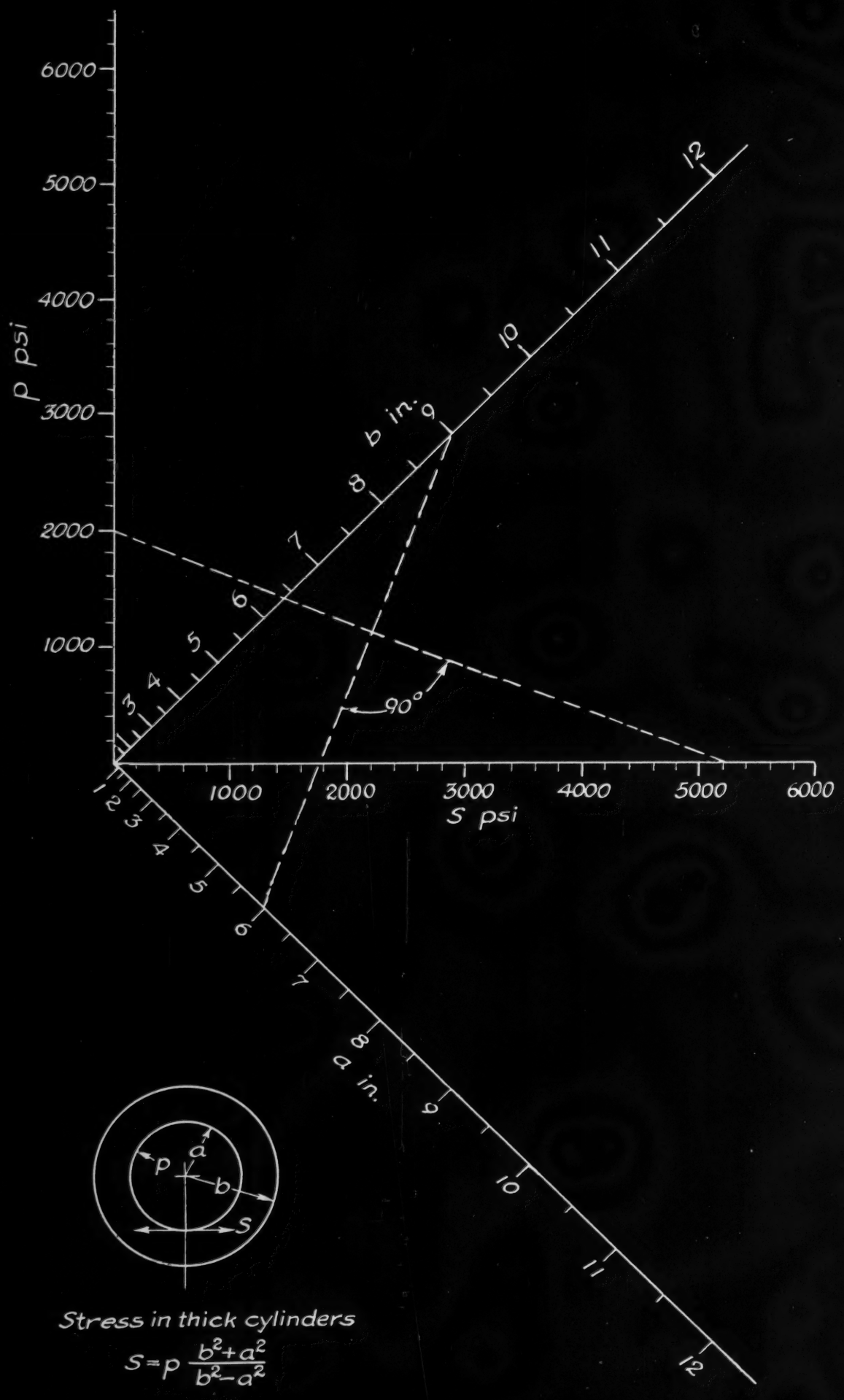
where s is the average tangential stress and t is the cylinder wall thickness.

The question frequently arises as to whether a cylinder should be regarded as "thick" (Equation 4) or "thin" (Equation 5). The determining factor is the ratio of working pressure to working stress, p/s, as the accompanying curve indicates. For example, if the internal pressure is one-tenth of the working stress the error in using the thin cylinder formula to solve for thickness is about 5 per cent. For engineering purposes this might be regarded as the boundary between thin and thick cylinders, corresponding to a thickness approximately one-twentieth of the internal diameter.

For the application of other theories of failure to the design of both thin and thick cylinders the reader is referred to the articles "Determining Wall Thickness for Pressure Vessels" (MACHINE DESIGN, April, 1942, Page 59) and "Designing High-Pressure Vessels and Piping" (MACHINE DESIGN, May, 1942, Page 77).



Curve shows percentage by which actual stress exceeds the allowable if the thin cylinder formula is used to find thickness, for various ratios of internal pressure to actual tangential stress



Stress in thick cylinders

$$S = p\,\frac{b^2+a^2}{b^2-a^2}$$

MACHINE DESIGN'S

Materials Work Sheet

Filing Number 13.00

Beryllium Copper

ASTM No. B120-41T

AVAILABLE IN: Rod, bar, sheet, strip and wire; hot-pressed parts in simple shapes

ANALYSIS:

Beryllium*	1.9 to 2.2
Additive elements to obtain special properties, max	.5
Impurities, max	.5
Copper	remainder

*Beryllium up to 2.3 per cent is permissible in rods and bars 1-inch and over in diameter or thickness.

PROPERTIES

TENSILE STRENGTH† (*psi*)

Sheet and strip	
Cold-rolled, annealed soft, max	80,000
Above plus precipitation hardening, min	150,000
Cold-rolled, ¼ hard (1 B&S No.), min	73,000
Above plus precipitation hardening, min	160,000
Cold-rolled ½ hard (2 B&S Nos.), min	80,000
Above plus precipitation hardening, min	170,000
Cold-rolled, full hard (4 B&S Nos.), min	95,000
Above plus precipitation hardening, min	180,000
Rods and bars	
Hot or cold-rolled, annealed soft (all sizes) max	80,000
Above plus precipitation hardening (all sizes) min	150,000
Cold-drawn (¼ to ¾-in. diam. or thk.) min	95,000
(Over ¾-in. diam. or thk.) min	80,000
Above plus precipitation hardening (all sizes) min	175,000
Wire	
Cold-drawn, annealed soft, max	80,000
Above plus precipitation hardening, min	150,000
Cold-drawn, ¼ hard (1 B&S No.), min	90,000
Above plus precipitation hardening, min	165,000
Cold-drawn, ½ hard (2 B&S Nos.), min	100,000
Above plus precipitation hardening, min	180,000

ELONGATION IN 2 INCHES† (*per cent*)

Sheet and strip	
Cold-rolled, annealed soft, min	35
Above plus precipitation hardening, min	5
Cold-rolled, ¼ hard (1 B&S No.), min	10
Above plus precipitation hardening, min	3.5
Cold-rolled, ½ hard (2 B&S Nos.), min	5
Above plus precipitation hardening, min	2
Cold-rolled, full hard (4 B&S Nos.), min	2
Above plus precipitation hardening, min	1
Rods and bars	
Hot or cold-rolled, annealed soft (all sizes), min	35
Above plus precipitation hardening (all sizes), min	3
Cold-drawn (all sizes), min	10
Above plus precipitation hardening (all sizes), min	2
Wire	
Cold-drawn, annealed soft, min	35
Above plus precipitation hardening, min	1.5
Cold-drawn, ¼ hard (1 B&S No.), min	5
Above plus precipitation hardening, min	1
Cold-drawn, ½ hard (2 B&S Nos.), min	2
Above plus precipitation hardening, min	.5

† Values conform to ASTM specifications.

MACHINE DESIGN is pleased to acknowledge the collaboration of the following companies in this presentation: The American Brass Co.; The Beryllium Corp. of Pennsylvania; Wilbur B. Driver Co.; The Riverside Metal Co.

YIELD STRENGTH† (*.5% elongation under load, psi*)

Sheet and strip	
Cold-rolled, annealed soft and precipitation hardened, min	90,000
Cold-rolled, ¼ hard (1 B&S No.) and precipitation hardened, min	92,000
Cold-rolled, ½ hard (2 B&S Nos.) and precipitation hardened, min	93,000
Cold-rolled, full hard (4 B&S Nos.) and precipitation hardened, min	95,000
Rods and bars	
Hot or cold-rolled, annealed soft and precipitation hardened (all sizes), min	85,000
Cold-drawn and precipitation hardened (all sizes), min	88,000

FATIGUE ENDURANCE LIMIT

Tests recorded in A.S.T.M. paper "Fatigue Tests on Some Copper Alloys" by A. R. Anderson and Cyril Stanley Smith show a variation from **47,200** to **61,500** pounds per square inch for highly polished bar specimens. Tests were made on rotating beam machines through 300 million cycles in air. Specimens were heat treated.

Other tests on strip at 100 million cycles show endurance strengths of **23,000** and **27,000** pounds per square inch for unheat-treated metal of half-hard and hard temper and **25,000** and **36,000** pounds per square inch respectively for the same metal in the heat-treated condition.

SHEAR STRENGTH (*typical values, psi*)

⅜-in. diam. specimens	
Soft, annealed	55,000
Soft, annealed then heat treated	95,300
Hard-drawn, 30% reduction	69,130
Hard-drawn, average heat treatment	84,600
Hard-drawn, maximum heat treatment	100,000

REDUCTION OF AREA§ (*per cent*)

.505-in. diam. specimens	
Hard-drawn	41.6
Hard-drawn and heat treated	3.5
Soft, annealed	56.6
Soft, annealed then heat treated	6.0

§ Values are from test results recorded in A.S.T.M. paper "The Tensile Properties of Some Copper Alloys" by Cyril Stanley Smith and R. W. Van Wagner.

Materials Work Sheet

CHARPY IMPACT STRENGTH (ft-lb)

(keyhole notched—typical values)

Soft annealed	59.7
Soft annealed then heat treated	7.3
Hard-drawn, 30% reduction	16.7
Hard-drawn, average heat treatment	6.1

PHYSICAL CONSTANTS

Melting Range	Solidus 864 C (1587 F) Liquidus 955 C (1751 F)
Specific Gravity	8.23± .02
Density (lb per cu in)	.297±.001
Maximum increase in density on heat treatment (per cent)	.6
Maximum decrease in length on heat treatment (per cent)	.2
Thermal Conductivity (soft or hard-drawn)	
(Btu/sq ft/sec/deg F/in) at 68 deg F	.14— .16
(cal/sq cm/sec/deg C/cm) at 20 deg C	.18— .2
Thermal Conductivity (precipitation hardened)	
(Btu/sq ft/sec/deg F/in) at 68 deg F	.16— .2
(cal/sq cm/sec/deg C/cm) at 20 deg C	.2— .25
Thermal Coef. of Linear Expansion	
(−50 to 100 deg C) per deg C	.0000166
(−58 to 212 deg F) per deg F	.0000092
Electrical Resistivity at 20 deg C	
Soft or hard-drawn (ohms per mil ft)	60
Heat treated (ohms per mil ft)	41— 59
Electrical Conductivity at 20 deg C	
Soft or hard-drawn (% of Int'l Ann'ld. Copper Std.)	17
Heat treated (% of Int'l. Ann'ld. Copper Std.)	18— 25

CHARACTERISTICS

Beryllium copper's most valuable quality is that it can be worked and formed in the soft annealed state and then greatly increased in strength and hardness by "precipitation" heat treatment. It has a relatively high electrical conductivity—which increases with the time of heat treatment—and excellent spring properties. Another outstanding attribute is its high fatigue resistance. In these respects it is unlike the usual kinds of copper.

The fine spring properties of this material are due in part to its inherently low drift rate under load and retention of high endurance value under corrosive conditions which ordinarily would impair the value of a steel spring. Beryllium copper is sensitive to slight variations in heat treatment and requires precise control for both solution annealing and precipitation hardening.

APPLICATIONS

Used extensively for instrument springs and parts, gears, propeller hub cones, cowl hinges, small machined parts, fuse clips, switch blades, vibrator arms, contact brushes, appliance plug clips, welding electrodes, diaphragms, leaf and helical springs, spring washers, sylphon bellows, cams, valve parts, watch parts, precision bearings and bushings, nonsparking tools, plastic molds, die-casting dies, etc.

FABRICATION

MACHINABILITY:

Compared to free-cutting yellow brass, the relative machinability of beryllium copper is approximately 20. It should be machined before the precipitation hardening treatment is applied and in this unheat-treated condition its machinability is similar to that of the nonleaded bronzes. Tungsten carbide tools are used to advantage for long runs, while for more modest production high-speed steel should prove adequate. This alloy requires the use of a lubricant as well as a coolant.

DRILLING:

Where short-run production is involved—not warranting the use of special drills—standard carbon or high-speed steel drills ground to an included angle at the point of 100 to 110 degrees prove adequate. Tough, stringy chips are produced in drilling this alloy and good results are obtained, particularly in deep drilling, through the use of high-spiral drills having a helix angle of about 40 degrees. Since beryllium copper work hardens rapidly, it is necessary to keep the drill cutting continuously to prevent glazing. Wherever possible, a lubricant is used. A speed of 50 to 125 feet per minute is practicable when using a lubricant.

REAMING:

As with drilling, carbon steel tools are adequate for short runs, while for long production machine reaming, high-speed steel or inserted tooth reamers prove best. Sufficient stock should be left in the hole when specifying the size of drilled hole to precede reaming, especially where wall thickness is small compared to the hole diameter. Such precaution will insure against burnishing action which results in undersize holes and excessively rapid wear of the reamer. Straight-fluted reamers have a tendency to chatter. Standard spiral-fluted reamers with 7 to 12-degree helix angle work satisfactorily, while the left-hand spiral, right-hand cutting types give excellent results.

ROCKWELL HARDNESS†

	SCALES					
	A	B	C	Superficial 30-T	Superficial 30-N	Superficial 15-N
Sheet and strip						
Cold-rolled, annealed soft, max	..	80	..	68	..	..
Above plus precipitation hardening, min	67	..	33	..	53	77
Cold-rolled, ¼ hard (1 B&S No.), min	..	72	..	62	..	..
Above plus precipitation hardening, min	68	..	35	..	55	78
Cold-rolled, ½ hard (2 B&S Nos.), min	..	82	..	69	..	..
Above plus precipitation hardening, min	69	..	37	..	57	79
Cold-rolled, full hard (4 B&S Nos.), min	..	93	..	77	..	..
Above plus precipitation hardening, min	70	..	39	..	59	80
Rods and bars						
Hot or cold-rolled, annealed soft, max	..	80	..	68	..	..
Above plus precipitation hardening, min	..	..	33	..	53	..
Cold-drawn (¼ to ¾-in. diam. or thk.), min	..	90	..	74	..	..
(Over ¾-in. diam. or thk.), min	..	80	..	68	..	..
Above plus precipitation hardening, (all sizes), min	..	..	38	..	57	..

TAPPING:

High-speed steel taps with ground threads are desirable for machine tapping with the rake angle ranging from 8 to 15 degrees and the cutting edges spiralled at the point by from 15 to 20 degrees. Unless an extremely close thread fit is required, it is advisable to specify a tap-drill size which will result in a 75 per cent depth of thread. 100 per cent threads are only 5 per cent stronger than 75 per cent threads, but require more than twice the power to tap and, in addition, present problems of chip ejection and correct tap design. An ample supply of cutting fluid should be used. For fine or moderate pitch threads, using high-speed steel taps, the tapping speed range is from 30 to 60 feet per minute. For coarse pitch threads, lower speeds are used. Where carbon steel taps are employed, speed is reduced by about one half.

STAMPING, FORMING AND DRAWING:

When punching and blanking beryllium copper, tools of high-carbon high-chromium steel are used with clearances the same as for blanking strip steel. Such tools stand up well providing the beryllium copper is cadmium plated before blanking. The plating provides lubrication for the tools.

In the unheat-treated condition, it has good forming qualities and is worked readily with good equipment and control. Due to the higher hardness of the alloy, more power, lower speed and stronger tools are necessary for drawing compared to deep-drawing brasses. It may be cold worked by any of the processes which are applied to phosphor bronze in comparable forms. Since it work hardens more rapidly than most copper alloys, annealing is required more frequently. When formed into various articles by cold working, beryllium copper in such forms as sheet, rod and wire does not require a solution heat treatment before hardening. The temper of the unheat-treated metal selected for forming a given article is governed by the amount of forming required. Sheet .05-inch and thinner in soft, ¼-hard and ½-hard tempers can be bent back flat on itself through 180 degrees when the bend is at right angles to the direction of rolling. For a similar sharp bend parallel to the direction of rolling, only soft or ¼-hard temper should be used. For operations which draw the sheet, soft and ¼-hard temper are satisfactory.

HOT WORKING:

Hot-working operations such as hot pressing, forging, drop forging, upsetting, and extruding may be effected at temperatures ranging from 1050 to 1475 degrees Fahr. Because the metal cools rapidly, the hot-working operation usually is started at the top of the temperature range. Thus, cooling does not reach the lower limit before the forming is completed.

When drop forging, it occasionally is necessary to subject the metal to reheating two or three times during the operation. At hot-working temperatures the plasticity differs from steel in that reductions cannot be as great and more hammer blows of less intensity are used than when forging steel. The duplex structure resulting from hot working makes it necessary to solution anneal the material to restore a condition which will respond to heat treatment. This is accomplished by holding the hot-worked parts at 1450 degrees Fahr. for from one to three hours (depending on the mass), and then quenching from temperature in water.

WELDING:

Fusion welding readily is accomplished by the carbon arc method using beryllium-copper or silicon-copper filler rod. Current is adjusted so that rapid melting is obtained—a speed of 10 or more inches per minute being desirable. Recommended procedure is to back the weld with copper so that the weld metal will be chilled quickly. When sufficiently rapid melting is effected, beryllium oxide has no chance to form because the base metal melts simultaneously with the fusion of the welding rod under protection of gases from the carbon arc. Hence, no flux is required. Peened welds made by this method and heat treated have shown tensile strengths of 140,000 to 150,000 pounds per square inch when beryllium-copper filler rod was used and 100,000 pounds per square inch when silicon-copper filler rod was employed.

Beryllium copper also can be joined by resistance, spot and seam welding. Pressures between electrodes and work usually are lighter than for steel and short "heat on" periods are desirable.

Gas fusion and metallic arc welding have not proved feasible because the tough film of beryllium oxide which forms prevents bonding of the weld and base metal. Thus far, no flux has been developed which will dissolve the old oxide and prevent the formation of new oxide during welding.

BRAZING:

No thoroughly satisfactory technique developed.

SILVER SOLDERING:

The following factors must be given due consideration:

Beryllium copper begins to melt at 864 degrees Cent.

Beryllium copper is given a solution anneal at 780 to 800 degrees Cent. and quenched preparatory to hardening.

Silver solder must melt and flow freely below 864 degrees Cent.

Silver-soldered joints must be solid enough to withstand quenching at 780 degrees Cent.

It will be seen from the above that the work must be handled quickly and carefully to keep all parts within the temperature range of 780 to 864 degrees Cent. The article must be quenched from the silver-soldering temperature (780 degrees Cent. or more), or must be reheated to 780 degrees Cent. for 30 minutes and quenched. The hardening heat treatment then is carried out at 300 to 330 degrees Cent. for a period of from one to three hours.

SOFT SOLDERING:

This is done after heat treatment because the temperature for the latter is higher than that for soldering. After the surface is cleaned thoroughly by scraping or scouring, the usual procedure is followed employing a customary flux. The metal is kept as cool as possible so that its temper will not be changed. A solder containing 90 per cent tin and 10 per cent zinc makes stronger joints than lead-tin solders.

HEAT TREATMENTS

HARDENING:

Beryllium copper is a precipitation-hardening alloy of the type in which the improvement in physical and mechanical properties is due to the "precipitation" of the gamma phase from the supersaturated alpha solid solution. As usually supplied in sheet, wire, rod, etc., the alloy has the solid-solution structure so that articles can be machined and more easily stamped or otherwise cold worked and then precipitation-hardened.

The hardening treatment consists in holding the articles at a definite temperature, generally between 275 and 330 degrees Cent., for the required period of time such as one or two hours. To control the quantity, particle size and distribution of the precipitate, the heating must be accurately regulated.

As a matter of fact, both temperature and time must be considered in precipitation hardening. Soft or solution-annealed material requires a longer time and a slightly higher temperature to bring about the maximum precipitation than does lightly cold-worked material. In similar manner, metal that is lightly cold worked requires somewhat more time and a slightly higher temperature for precipitation than metal that is severely cold worked. It is not possible to obtain as great strength and hardness in heat treating soft material as in heat treating the harder types.

Special combinations of properties, such as increased ductility, electrical conductivity and resistance to elastic drift in springs, may be obtained by special precipitation-hardening treatments. When such properties are required the individual manufacturer should be consulted for specific instructions.

ANNEALING:

When required between cold-working or forming operations, annealing is effected by heating the metal to 800 degrees Cent., holding it there for 15 to 30 minutes and then immediately quenching in cold water. Applicable to any cold-worked beryllium copper, this treatment brings the alloy to its softest condition.

The purpose of annealing after welding, silver soldering or hot working, is to bring into solid solution the duplex alpha-plus-beta structure which results from heating in the hot-working range. After silver soldering, it may be necessary to allow the metal to cool to 780 degrees Cent. so that the solder can solidify before quenching. Any gas, oil or electric furnace in which the temperature can be controlled accurately at 800 degrees Cent. is suitable for annealing. Most salt baths operated at this temperature have a corrosive effect on beryllium copper and therefore are not recommended.

A furnace with a controllable atmosphere is highly desirable in annealing this metal. Hydrogen gives a bright anneal without harming the alloy in any way.

PICKLING:

Annealing, forging or heat treating of beryllium copper forms a surface oxide which usually can be quickly and thoroughly removed by a three to five-minute immersion in a warm solution made by pouring two parts of commercial concentrated sulphuric acid into one part of water. This strong solution is very corrosive and must be handled with caution. If a weaker solution is desired, the work is left for five or six hours in a solution made of one part sulphuric acid and ten parts of water, with the same result. This treatment leaves a red copper film on the surface which is removed easily by a quick immersion in the usual nitric acid bright dip, or in an acid solution composed of 1½ to 2 pounds sulphuric acid, 2 to 3 pounds potassium bichromate and a cubic foot of water.

It is of great assistance in pickling, particularly with finished articles, if all oil, grease and soap are removed from the work before annealing or heat treating. On heating in the precipitation-hardening range, or in nonoxidizing atmospheres at 800 degrees Cent., greasy material forms a gummy film on the surface which prevents the acid from reaching the metal.

RESISTANCE TO CORROSION

Beryllium copper shows in general the same resistance to corrosion as pure copper. It offers excellent resistance to industrial, marine and rural atmospheres and good resistance to natural fresh water and sea water.

Acids: Beryllium copper may be used in contact with hot or cold dilute sulphuric acid and with cold, concentrated sulphuric acid. It may be used also with cold, dilute hydrochloric acid.

Alkalies: Good resistance to cold, concentrated alkalies and to hot and cold dilute alkalies.

Salts: Good resistance to sulphate salts and fair resistance to chloride salts.

Sulphides: Poor resistance.

Beryllium copper is not resistant to ammonium hydroxide, ferric chloride, ferric sulphate, acid chromates, or mercury solutions. It should not be exposed to the halogens (fluorine, chlorine, bromine and iodine) at elevated temperatures.

GALVANIC CORROSION

Beryllium copper will exhibit galvanic corrosion effects similar to pure copper. In general, it may be coupled safely with other copper alloys. However, a relatively large area of the material should not be connected galvanically to a small area of brass high in zinc, nor to small areas of iron, zinc or aluminum, unless the whole assembly can be protected with paint. If a coating of paint is not practical, beryllium copper should be insulated from contact with these metals.

DATA ON STOCK FORMS

Temper Data

B & S (Brown & Sharpe) Nos. Hard	General Trade Terms	Strip Per Cent Reduction	Rockwell Hardness Standard
Soft Annealed	Dead Soft	0.0	B 46-65
1 No.	¼ Hard	10.9	B 72-85
2 Nos.	½ Hard	20.7	B 85-93
3 Nos.		29.5	B 89-97
4 Nos.	Full Hard	37.1	B 91-99

Cold-drawn Rods, Bars and Wire

STANDARD DIAMETER TOLERANCES†

Diam. or Distance Across Flats	Tolerance (inches) Plus or Minus Rounds	Hexagons, Octagons
RODS AND BARS		
Over .150 to .5	.002	.004
Over .5 to 1	.003	.005
Over 1 to 2.5	.004	.006
Over 2.5	.2%*	.4%*
WIRE		
.010 and under	.0002	....
Over .010 to .020	.0003	....
Over .020 to .030	.0005	....
Over .030 to .040	.0007	.002
Over .040 to .050	.0008	.003
Over .050 to .060	.001	.003
Over .060 to .080	.0015	.004
Over .080 to .150	.002	.004
Over .150 to .500	.002	.004
Over .500 to .750	.003	.005

Note: When tolerances are specified as all plus or all minus, double the above values.

*Expressed to the nearest .001-in.

Hot-rolled and Forged Rods and Bars

STANDARD DIAMETER TOLERANCES†

Diameter (inches)	Tolerance (inches) Plus or Minus
.250	.020*
Over .250 to .375	.010
Over .375 to .750	.015
Over .750 to 1.25	.020
Over 1.25 to 1.5	.030
Over 1.5 to 3	1/16
Over 3	1/8

* This tolerance is all plus.

Note: When tolerances are specified as all plus or all minus, double the above values.

MATERIAL DESIGNATIONS

ASTM	B120-41T
U. S. Army Air Corps	11070-A
U. S. Navy	46C10 (INT)
SAE	4650A

PROFESSIONAL VIEWPOINTS

MACHINE DESIGN welcomes comments from readers on subjects of interest to designers. Payment will be made for letters and comments published

"... more knowledge of spring design"

To the Editor:

Dr. Wahl's article in your March issue, "Frequently Overlooked Factors in Design of Springs", is very interesting, as are all his articles on spring design.

I think that all manufacturers have found that the more knowledge of spring design that can be made available to users of springs, the easier it becomes to satisfy customers' requirements. Many of the expedients mentioned by Dr. Wahl and others have come into common use to assist in overcoming defects in design due to inexperience. There are, of course, numerous cases where other considerations so limit the space available for springs that all kinds of ingenious designs must be resorted to in order to attain the required performance.

Those of us interested in literature on springs are eagerly awaiting the author's forthcoming book which I am sure will be of great assistance in the manufacture and use of mechanical springs of all kinds.

—H. F. CLARKE
Director of Spring Mill Prod.
American Steel & Wire Co.

"... for expanding existing controls"

To the Editor:

Will you please forward a copy of the article, "Engineering A System for Engineering," by John T. Davidson, which appeared in the February issue of MACHINE DESIGN? The system of engineering control as outlined in this article is somewhat similar to the one we have in operation. However, we feel that an article such as this can be of great assistance in expanding and improving the existing controls. We would appreciate a copy of this article for reference purposes.

—A. C. WEDGE, *Production Engineer*
Ozalid Products Division

"... conservation, substitution"

To the Editor:

The appearance in an engineering journal of articles by an eminent metallurgist such as H. W. Gillett is a source of interest and gratification. While intensive specialization is undoubtedly the keynote to modern industrial progress, the realization is developing that it is possible to overreach ourselves in this matter. In addition to being an expert in stress analysis and other phases of machine design, the designer also needs to have a good fundamental knowledge of the materials he uses. Metallurgical assistance is always advisable, but the engineer cannot be wholly dependent upon it if he would achieve the greatest economy of material and the highest satisfaction of product.

Realization that there is no such thing as a material that is the panacea of failure troubles is also important. Mr. Gillett has aptly put this at the end of his first article: "The search for a metallurgical substitute developed the fact that feasible engineering modifications were so much more potent than steel composition . . ." in strengthening the part. It would seem that if any failure problem is so close to the narrow edge that a change in steel would satisfy it, the "factor of safety" is too low for good design.

Interchangeability of Materials

These articles are most timely and contribute toward conservation of material, importance of which is recognized in winning the war, as well as in the postwar period when it will be necessary to produce without lavish waste.

It is interesting to follow these thoughts through the series. The interchangeability of materials is emphasized in a study of variations between heats as compared with variations between analyses, with the conclusion that ". . . the spread in properties *from heat to heat* in any one grade is about as wide as between the grades." This should be considered by those who feel that one analysis cannot substitute adequately for another. ". . . it is immaterial . . . by what alloying and additional elements or combinations thereof the final mechanical properties are produced."

Mr. Gillett's comments upon the demand for core toughness in case hardening are much to the point. "But when such a case is deformed enough to crack, the crack propagates rapidly even through tough cores, so the piece *as a whole* is brittle."

His comments on the use of the salt spray corrosion test for parts not to be subjected to conditions even remotely approaching this test could well be underscored. Undoubtedly many tons of protective coatings have been applied beyond the needs of the application. It is inter-

esting to note "that the salt spray test decisively reports cadmium plate as superior to zinc plate—but for atmospheric corrosion protection on steel in actual service the two are often equally useful. . . ." Under the subject of wear we read "some so-called wear testing devices sometimes press a rotating disk . . . against a flat surface of the metal to be tested. . . ." Upon which he comments ". . . as a wear test, it is close to useless."

One cannot help but appreciate the complexities of an actual service problem as compared with the simplicity of the specification tests upon which we are inclined to base decisions. More and more it must be appreciated that we should look forward to the end use rather than backward to the tests for our decisions. "Resorting to simulated service tests is a confession of ignorance . . . but it is far better to confess ignorance . . . than to specify by guess."

—R. E. Orton, *Chief Engr.*
Acme Steel Co.

" . . . most complete coverage"

To the Editor:

In reading a copy of Machine Design recently I noticed the sections "Engineering Data Sheet" and "Materials Work Sheet". I was profoundly interested in these sheets, especially the material sheets, since they are the most complete coverage on the subject that I have been able to locate.

It occurred to me that you may have back issues of these material and data sheets available. If this is the case, I would appreciate knowing their prices and how it is possible to obtain them for use in my daily work.

—Nevin J. Blum
York, Pa.

" . . . revising data on materials"

To the Editor:

The "Materials Work Sheet" covering No. 12.00 phosphor bronze in your February issue proved of great interest to us—especially so as at the present time we are engaged in revising our data on materials and are desirous of making these as complete and up-to-date as possible.

Wartime conditions have made it imperative that our source of information conform to present-day requirements and availability. It is necessary sometimes to amend our specifications accordingly. We would, therefore, appreciate any further information which may have been issued or which you may have at your command at the present time on various materials such, for instance, as the article referred to. We would be pleased to purchase any of the back numbers relative to the above or to meet the cost of such compilations. This information will be of great value to us.

—A. Lynden Lester
Asst. to Chief Engineer
Foster Engineering Co.

It is planned to reprint the entire series of "Materials Work Sheets" in looseleaf folder form as soon as practicable.—Ed.

" . . . vibration, flexibility, and heat dissipation"

To the Editor:

While I find myself in accord with the information furnished in the article "Hydraulic Lines . . . Which Material, What Size?" which appeared in your December issue, there are a few phases of the subject which I feel should have been given more emphasis, namely: Effects of vibration, conduit rigidity and heat dissipation.

Great care should be taken in the application of metal tubing and fittings in installations where vibration is a factor. Our experience has been that there should be very little tension set up in fastening conduit to machinery because excessive tension tends to amplify vibrations.

On industrial lift trucks, where the pump is driven by a gasoline engine, we have found that vibration due to engine and pump impulses tends to synchronize with the rate of movement of the relief valve. Under these conditions we determined that any rigid piping which did not have a flexible line at one end to absorb these vibrations would tend to cause chattering at extremely high pressures and, in many cases, shake the fittings loose from the tubes.

There is a distinct increase in impulse as the pressure goes up. In some jobs where we were working at a range of 3 to 30 gallons per minute at 1200 to 1400 pounds pressure, we had to dampen relief valves because the rigid piping could not be altered due to government orders which forbid changing, even though we found that if a short piece of flexible high-pressure hose were put into the line to eliminate the rigidity, the noises ceased.

There is often a tendency in installing metal piping to put it under initial tension by forcing it into place. Under such circumstances, if the mountings of the valve, relief valve and pump are rigid and there are any soundbox effects from the reservoir or any of the mountings, the impulses set up will resound. This gives rise to disconcerting noises which many times are detrimental to the sale of the product. If short lengths of flexible hose are used in connecting the metal tubing to the rigid parts of the system such as the valve, pump and reservoir, these objectionable sounds will cease.

In regard to heat dissipation, we have made many installations in which large volume pumps were used to give the required speed and where the reservoir size was limited. For example, on one current job, a tractor mounting has a 63 gallons per minute pump with a reservoir that holds a maximum of eight gallons. The oil in the entire system, however, including the lines and cylinders, is about 18 gallons all told. In this system the velocity in the high-pressure lines was kept to a maximum of 900 feet per minute and where possible, 500 to 600. The intake velocity to the pump was held to a maximum of 400 to 450. This was feasible because there was sufficient metal in the conduit in contact with the fluid to dissipate the heat buildup. Because of the heat dissipation factors involved, extra heavy pipe was used rather than light metal tubing.

—W. T. Stephens
Vice Pres., Sales and Engrg.
Hydraulic Equipment Co.

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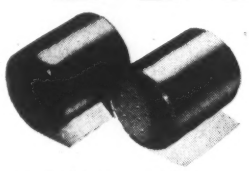
Bronze on Steel

PATENTED



Available in a wide range of sizes as Sleeve Type Bearings or fabricated into washers, thrust plates, etc. Write for new literature.

Combining a high grade bearing bronze with strip steel provides a new and unusual bearing material. Its use as SLEEVE TYPE Bearings enables manufacturers to increase speeds and loads . . . to gain longer bearing life with smoother operation . . . plus greater resistance to shock and to wear. *Pre-Cast* Bearing BRONZE ON STEEL produces a thin wall, laminated type of bearing. The fabricating process, essentially a series of stamping and forming operations provides accuracy and precision at a low unit cost.

While Pre-Cast Bearing BRONZE ON STEEL was developed primarily for sleeve bearings it also serves many other important applications in industry. It is an excellent material for stampings, washers, guide strips, or other flat pieces. It is available in coils with a maximum width of 5½" and a range of thickness from 1/32" to 3/32".

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SLEEVE BEARING HEADQUARTERS

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The MOST COMPLETE SLEEVE BEARING SERVICE in the WORLD

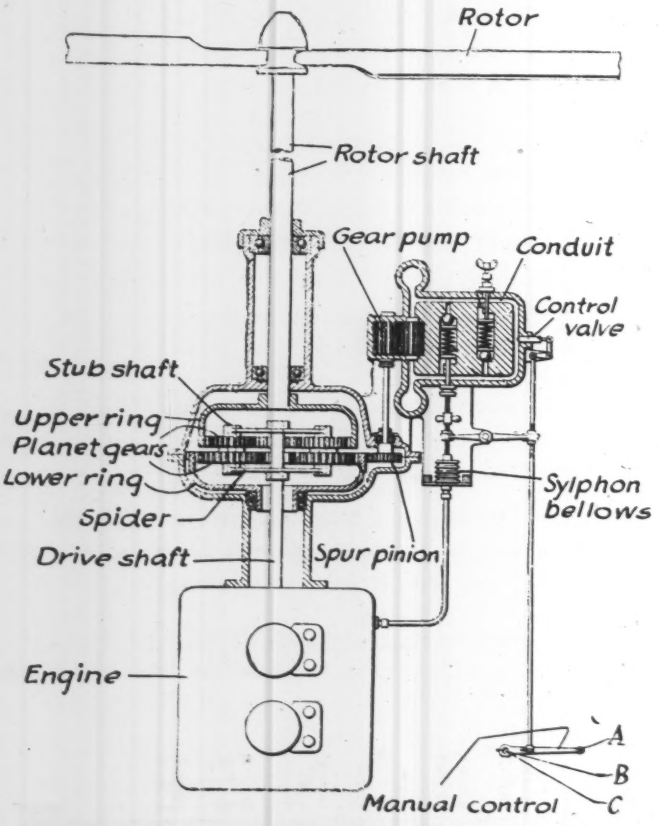
Noteworthy Patents

Oil Circuit Provides Transmission Control

REQUIREMENTS of the drive mechanism for transmitting power to the rotor of a helicopter include: Clutch action; freewheeling; variable-speed reduction during starting; braking; damping of the clutch and freewheeling operation; and disengaging the engine and rotor elements either manually or automatically under overload conditions. These and other features are incorporated in a drive covered by Patent 2,340,241, recently assigned to Bell Aircraft Corp.

Accompanying drawing shows an engine, rotor and power transmission mechanism, illustrating schematically the principle of operation. A tubular housing extending from the engine carries the transmission and also supports the rotor shaft. The engine is provided with a driveshaft extending into the housing and carrying a pair of spiders which support the ends of two stubshafts. On each stubshaft is supported a planetary gear unit comprising a pair of interconnected spur gears which are free to rotate about the stubshaft.

One pair of planet gears meshes with an internal ring gear keyed to the end of the rotor shaft. The other meshes with a second internal ring gear mounted on bearings in the housing which extends from the engine. If this lower ring gear is held against rotation relative to the housing, rotation of the engine driveshaft will be translated into planetary rotation of the planetary gear units and the engagement between the planet gears and the upper ring gear will cause the latter to rotate and drive the rotor. In proportioning the gears, provision can be made for any necessary speed reduction between the engine and the rotor.



"Fixed" ring gear of planetary transmission is coupled to oil pump operating in a circuit which can be blocked to lock the gear or opened to permit slip

Restraint of Ring Gear Governs Speed

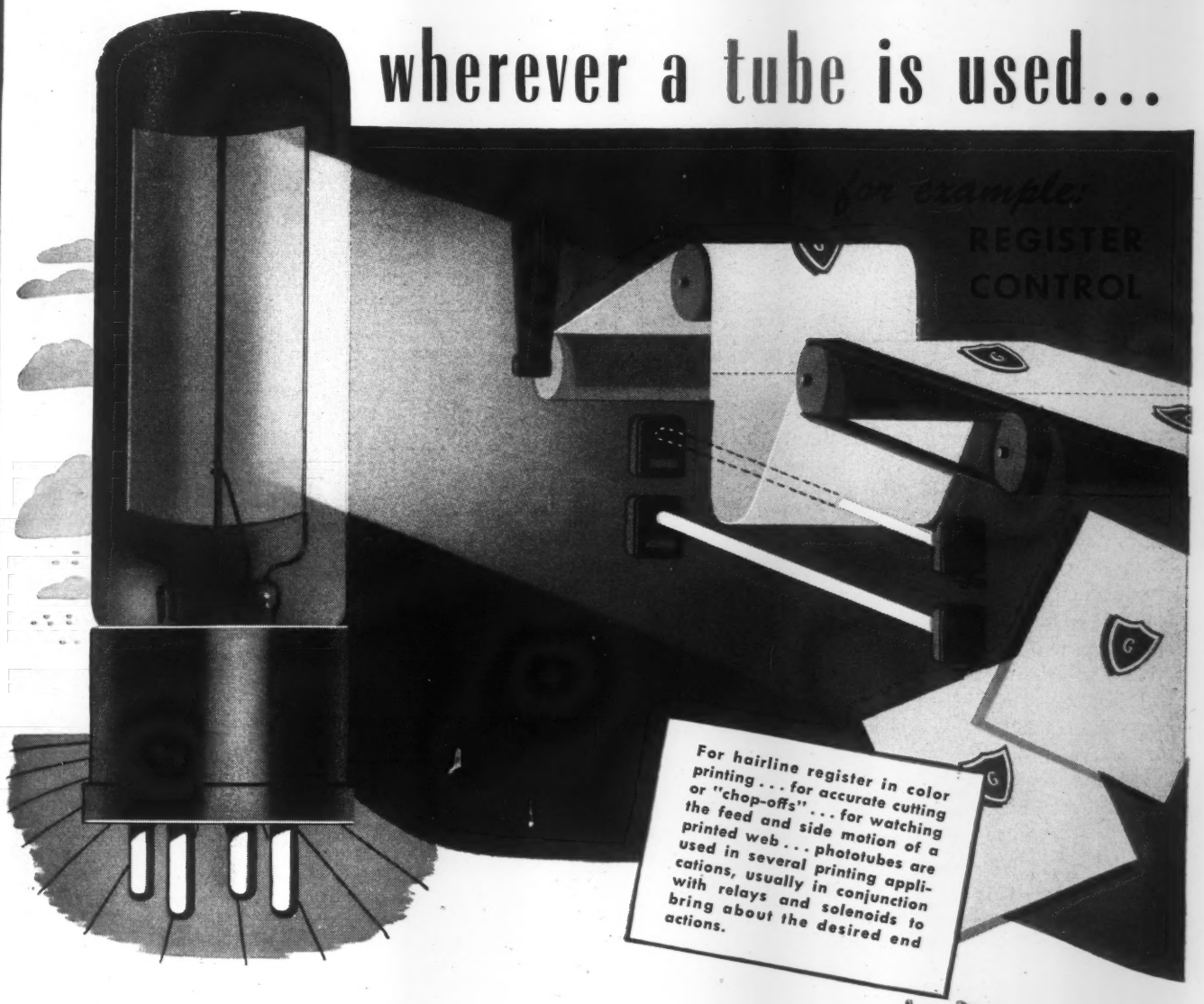
If the lower ring gear is unrestrained it will rotate in its bearings in response to planetary rotation of the spider and planet gear units relative to the upper ring gear. Under these conditions of operation no power will be transmitted to the rotor shaft and the engine shaft and rotor shaft will in effect be disconnected. Also the rotor will be free to rotate relative to the housing and therefore, whenever the lower ring gear is unrestrained, the engine may idle relative to the rotor or the rotor may freewheel relative to the engine. Further, if the lower ring gear be permitted to rotate in response to the engine driving force at various speeds which are less than the unrestrained speed of rotation, the system will translate engine power output into rotation of the rotor at speeds which will depend upon the rate at which the ring gear is allowed to slip.

To control the operation of the lower ring gear a spur pinion is arranged to mesh with an external gear extending around the outside of it. The spur pinion is connected by a shaft to one of the elements of a gear pump which is capable of circulating oil or other fluid through a conduit system in communication with the inlet and outlet of the gear-pump casing. A manually operated control valve is used to block the circulating movement either partially or totally. When the conduit is only partially blocked, circulation is retarded and the gear pump imposes a retarding action upon the lower ring gear but permits it to turn slowly. If the control valve is adjusted to block circulation totally, the gear pump device will thereby be blocked and will lock the ring gear against rotation.

When the control valve is wide open, little resistance is offered to the passage of oil. The gear pump and its associated spur pinion offer less resistance to the lower ring gear than the rotor offers to the upper ring gear, so that the rotor remains at rest.

Overload release in the form of two check valves between the inlet and outlet side of the circuit permits the power transmitting mechanism to slip under conditions such as when the engine suddenly stops or the rotor becomes jammed. The spring of the left-hand check valve is backed up by a slide rod extending outside the casing and interconnected with the manual control lever. When

wherever a tube is used...

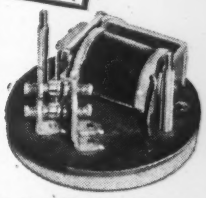


For hairline register in color printing . . . for accurate cutting or "chop-offs" . . . for watching the feed and side motion of a printed web . . . phototubes are used in several printing applications, usually in conjunction with relays and solenoids to bring about the desired end actions.

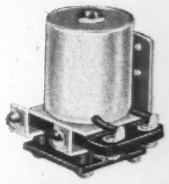
THERE'S A JOB FOR *Relays* BY GUARDIAN

In the electronic circuit there is usually a sensitive relay similar to Guardian Series 5, to control a heavier current in response to the weaker "signal" of the phototube. In some applications, however, the current to be handled may be greater than the contact capacity of the sensitive relay. In this case a power relay or solenoid contactor is controlled by the sensitive relay. Guardian series SC-5 is typical of this type of contactor.

Consult Guardian wherever a tube is used—*however*—Relays by Guardian are NOT limited to tube applications but may be used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.



SERIES 5 D. C. RELAY. Maximum switch capacity—two normally open, two normally closed, or DPDT contacts. Resistance range .01 up to 15,000 ohms. Send for bulletin 14.



SERIES SC-5 SOLENOID CONTACTOR. Contacts rated at 75 amps. continuous, 300 amps. surge. Contact combination—single pole single or double throw. Coil operates on 18-28 volts D. C. and consumes 7 watts at 24 volts D.C. continuous. Send for bulletin SC-5.

GUARDIAN ELECTRIC

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the manual control lever is moved down to the position indicated by C, the control valve is closed and the check valve spring compressed so that oil will be unable to circulate through the gear pump (unless a severe overload occurs) and the lower ring gear will be locked. Gradual movement of the manual control from A to C permits a variable ratio and enables the rotor to be brought up to speed gradually.

Right-hand check valve permits release of excessive fluid pressure within the conduit in case the engine goes dead in flight or is suddenly throttled back, and allows the rotor to freewheel to some extent, avoiding undue deceleration forces upon it.

Avoids Operation at Critical Speed

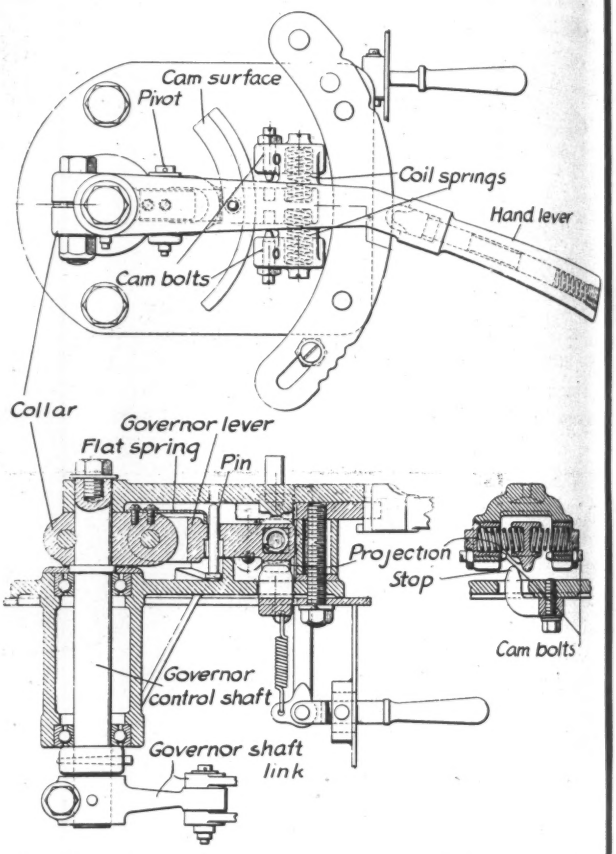
WHILE the problem of critical speed in internal combustion engines often can be considerably reduced by proper design, it quite frequently happens that some particular critical speed is present at which it is undesirable to operate the engine for any substantial period. To prevent the operator from running the engine at this particular speed and yet at the same time require no conscious effort or thought on his part, a method of control covered by Patent 2,339,117 assigned to the Baldwin Locomotive Works has been developed recently.

Shown in the accompanying illustration, the control consists of a hand lever by means of which the operator changes the setting of the speed governor. However, the hand lever is not directly attached to the governor control shaft but operates through a mechanism which prevents the governor control shaft from ever assuming a position corresponding to the critical speed of the engine. Upper end of the governor control shaft has a collar rigidly secured to it and supporting the vertically movable governor lever which is pivoted to the collar about a horizontal pin. A flat spring maintains the governor lever normally in a downward position as shown.

Movement of the hand lever is transmitted to the governor lever through a pair of coil springs interposed between the governor lever and a pair of arms carried by and projecting downwardly from the hand lever on opposite sides of the governor lever. In order to have the engine speed pass rapidly through the critical and to prevent the operator from running the engine at its critical speed, means are provided for temporarily restricting movement of the governor lever just before it reaches a predetermined position, even though the hand lever continues to be moved. After a predetermined movement of the hand lever beyond the critical speed position the governor lever is automatically released so as to move the governor shaft suddenly to a higher-speed position above the critical speed.

To accomplish this operation the governor lever is provided with a small projection adapted to engage a stop which projects upwardly into its path. The stop is secured to the underside of the stationary frame. When stops engage each other the governor lever cannot move even though the hand lever continues its movement. Continued movement causes one of the coil springs to be compressed so that the governor lever when lifted about its pivot to clear the stops is rapidly moved by the springs to a normal central position between the arms of the hand lever. The governor lever upon reaching its central position is then subject to further actuation by the hand lever. This will quickly adjust the engine speed past its critical point.

To raise the governor lever, two cam bolts are threaded in the lower end of the arms of the hand lever. These



Throttle lever actuates governor control through mechanism which precludes a setting corresponding to critical speed at which severe engine vibration may occur

cam bolts have tapered inner ends adapted to engage cam surfaces formed on the underside of the governer lever whereby, during increasing speed of the engine, the compression of the left-hand coil spring is released by the pin engaging the cam surface and raising the governor lever. Likewise when the engine speed is being reduced by movement of the hand lever the right-hand spring is compressed until the governor lever is released by engagement of the cam bolts and cam surface.

If it is desired to compel the governor lever to follow the hand lever quickly except at the critical speed, a pin is provided which extends through the governor lever and into an opening in the hand lever. Lower end of the pin rests upon a stationary cam surface whose low point occurs at the critical speed position, thereby allowing the pin to fall out of the opening and permitting the governor lever to be controlled by the stop lugs. When the governor lever is on either side of the critical speed position, the cam will move the pin upwardly into the aligned opening to make the governor lever and hand lever operate as a positive unit.

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Hence, stainless and Nickel alloys are specified widely for acid heaters and caustic coolers, for high-pressure autoclaves and vacuum evaporators, for cracking towers and polymerization reactors, for shipping drums and tank cars, for pumps, piping and storage tanks, for agitators and settlers, for stills and digestors—for every type of equipment that converts laboratory experiments into full-scale chemical operations.

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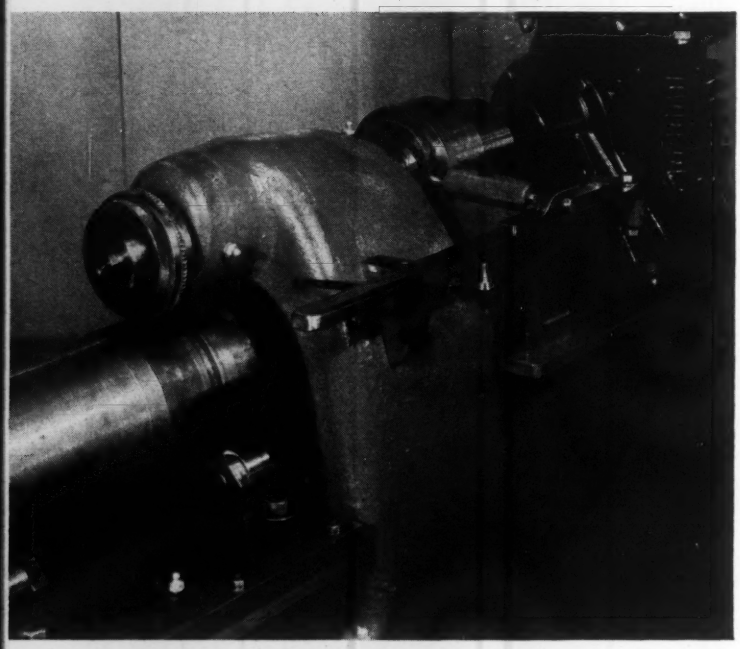
Applications

of Engineering Parts, Materials and Processes



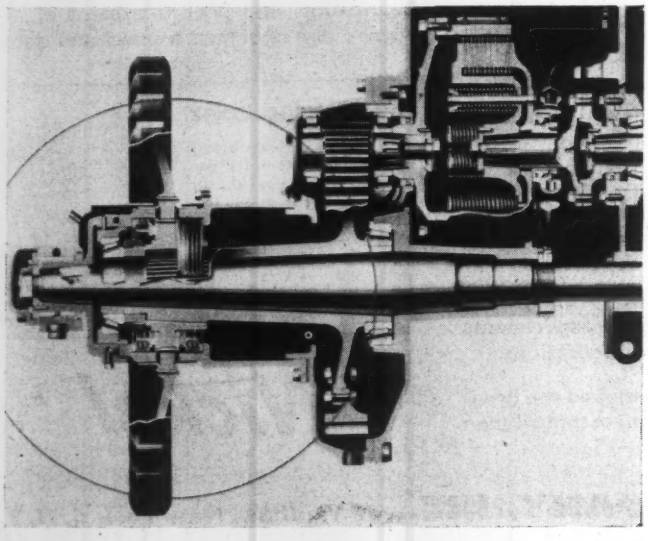
Rotates Shell Through One Revolution

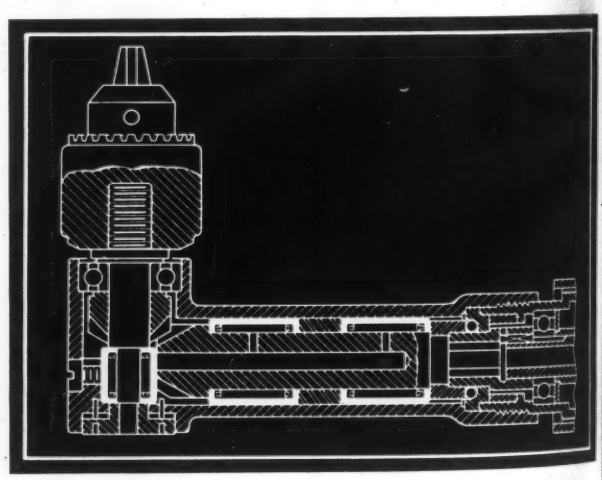
EMPLOYED for marking ordnance data on the rotating band of large Naval shells, the Matthews machine shown at left uses a Hilliard single-revolution clutch to give the required rotation with positive stop between operations. Because the shells already are loaded and fused they are highly explosive and it is imperative that the mechanism be stopped during loading and unloading.

In operation, a cradle roll nest is pulled toward the front of the machine and the shell placed in position. The nest is then pushed back into marking position and the clutch engaged by means of a hand lever. A spring-controlled trip lever automatically returns to position for disengaging the clutch at the end of one revolution, the trip lever being connected with a rod or pin which rides on the contour of the clutch trip cam. Each shell is marked approximately 240 degrees around its circumference, corresponding to one revolution of the marking wheel.

Permit Compact Drill Design

IN THE Chicago Pneumatic drill, shown at right, use of Torrington needle bearings enables the angle head to be made small and compact, permitting the machine to be introduced into small openings when drilling rivet holes, etc., in aircraft construction. Small size and high load capacity of these bearings were the chief factors influencing their selection.





Bonds Cork and Copper for Shaft Seal

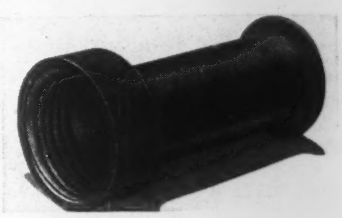
SEALS which keep dirt out of the final drive on Caterpillar tractors consist of cork-faced bellows, shown at the center of the circle in the photograph at left. A major problem in seal design—the cementing of the cork section to the copper bellows—was solved effectively through the use of Vinylseal adhesive cement. Made from a vinyl resin compound, this adhesive bonds securely to nonporous surfaces, preventing the passage of water, oil or dust. The cementing is done easily on a production basis and has increased seal output about ten per cent.

TALK TO TAYLOR NOW ABOUT THE PART LAMINATED PLASTICS WILL PLAY IN YOUR POST-WAR PRODUCTS

To help you *now* with your post-war plans, we have created and manned a Post-War Development Department. This Department has *no duties* other than those of discussing with forward-looking manufacturers the contributions that Vulcanized Fibre, Phenol Fibre, or Phenolastic Fibre* can make to the performance and economy of the products of tomorrow.

Before you decide that a product or a part can best be made from aluminum or glass, steel or wood, or any other material, it will pay you to find out whether or not that product or part can be made better, cheaper, or faster in laminated plastics. Consultation on such problems with the engineers in our Post-War Development Department is yours for the asking, without cost or obligation. Write us, in complete confidence, about your plans and problems.

*A new development by which finished sheets of Phenol Fibre can be reheated in your own plant and formed permanently to almost any shape in inexpensive, wooden dies.



Mass-produced by machining from tubes of Phenol Fibre, this radio part combines light weight, high dielectric quality, low moisture-absorption, and the ability to stand severe shock. Whatever combination of qualities you require, it's a rare case indeed that can't be solved by Laminated Plastics.

POST-WAR DEVELOPMENT DEPARTMENT OF

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LAMINATED PLASTICS: VULCANIZED FIBRE • PHENOL FIBRE • Sheets, Rods, Tubes, and Fabricated Parts

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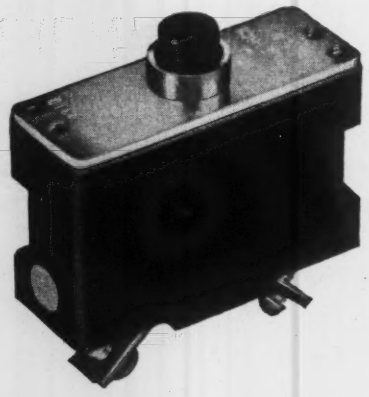
New PARTS AND MATERIALS

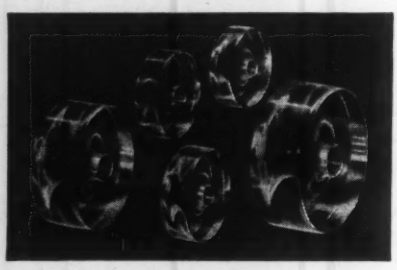
Push-Type Circuit Breakers



PUSH-TYPE circuit breakers have been added to the line of aircraft electrical control devices manufactured by the Regulator division of Square D Co., Detroit. Developed to provide an improved unit for use in protection of low voltage circuits not requiring switching, the Class 9310 manual reset circuit breaker is available in sizes 5 to 50 amperes, and is built in accordance with Navy specifications. Although designed for aircraft use, these devices are suitable also for boats, tanks and other mobile units having power sources up to 30 volts direct current. Protection against small momentary overloads as well as instantaneous protection on heavy overloads and short circuits is given by a metallic trip element. After tripping it is necessary only to push and reset button to its farthest position. Of non-trip-free construction, all devices are equipped with luminous indicating rings.

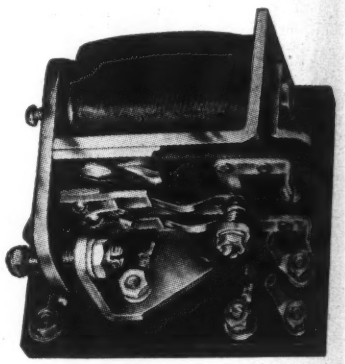
Glass Ring Jewels

DEVELOPED FOR aircraft instrument bearings by General Electric Co., Schenectady, N. Y., glass ring jewels are also being furnished for many other applications such as meters and instruments. Five sizes are available for



use in precision measuring equipment, and other shapes and sizes for applications such as thread guides, weighing scales, automobile and truck speedometers, and similar instruments and devices. An outgrowth of work in developing glass vee jewels, the rings are supplied ready to set. They can be press-set or spun-set into bearing plates and other elements in the same manner as sapphire rings. Surface of the hole in the glass ring is fire-polished and is not touched subsequently. The flat surface opposite the "bell end" of the hole is highly polished by brushing with an abrasive. The five bearing sizes include three outside diameters: .1, .0787 and .064-inch.

Sensitive, Snap-Action Relay



RECENT DESIGN simplification of the new Type 79XAX sensitive snap-action relay, announced by Struthers-Dunn Inc., 1931 Arch street, Philadelphia 7, makes it both practical and economical for use in a wide variety of applications. The relay is so designed that its armature practically completes its travel before the contacts snap with a positive action to the corresponding position. This plus the fact that contacts remain closed with full pressure to the instant of transfer to the other position permit the unit to be used in a number of ways. Included in its applications are: Overcurrent protection, particularly in the range of 10 to 100 milliamperes; overcurrent protection in connection with shunts furnishing potentials in the range of 1 to 100 millivolts; pulsing circuits where the relay must "pump" or "scratch its own back"; numerous sensitive vacuum tube circuits; and many others. By means of various circuit arrangements a greater degree of sensitivity may be obtained. Normal sensitivity, however, is .01 watt. Contact arrangement is single pole, double throw, and contact rating 10 amperes 110-volt alternating current, and 10 amperes 24-volt direct current. Balanced construction withstands 10g vibration and shock. Coil resistance is available from ¼ to approximately 30,000 ohms. The unit weighs 10 ounces and is 2¾ x 3 x 1¾ inches in size.

A.C.-D.C. Power Supply Systems

OF INTEREST to the aviation industry and its allied fields are the new A.C.-D.C. power supply systems produced by the Eclipse-Pioneer division, Bendix Aviation Corp., Teterboro, N. J. These provide a dependable source of alternating current for operation of various radio devices, and direct current for operation of direct-

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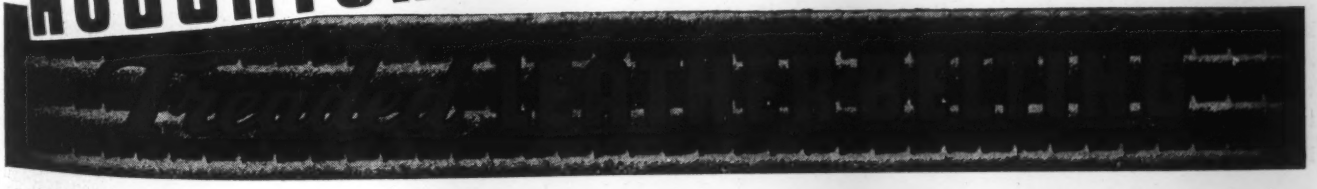
Nature gave it the fibrous structure. Science has restored its life by nourishing those fibers after tannage. The result is permanent pulling power, year after year, with only occasional dressing. Insist on first-grade leather!

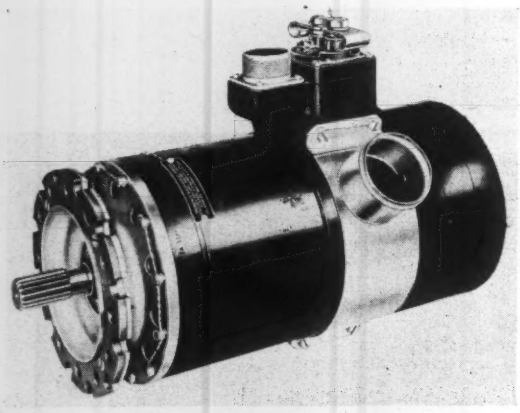
Houghton's special mineral VIM tannage, as well as its combination OKAY leather, is further improved for grip and pull by adding a patented tread to the pulley side. This tread increases contact tension—minimizes slip.

Other merits—water-and-oil-proof treatment, high C/F, elasticity, pliability, high tensile strength—add up to the greatest value you can get in a power transmission belt. For full proof, write E. F. HOUGHTON & CO., Philadelphia.

HOUGHTON'S



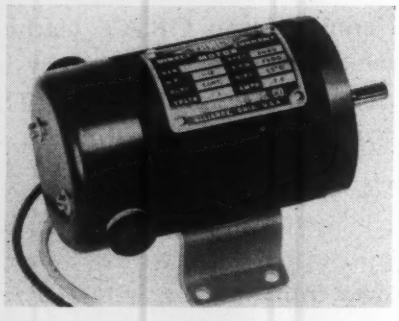
current electrical equipment. Generators are designed for mounting on main engine generator drive pads of aircraft, incorporating provisions for generator blast cooling. They are available in various capacities ranging from 60 to 200 amperes at 28.5 volts direct current and 10.4 to 30.5 amperes at 115 volts alternating current. Both alternating and direct-current rated outputs are available



simultaneously over the entire rated speed range. Tubular armature shaft and air-blast cooling contribute to maintaining safe operating temperatures. A floating type flexible torque drive shaft absorbs the torsional vibration and compensates for any slight misalignments between engine and generator drives. The regulators provide continuous regulation, with a minimum of radio interference due to absence of vibrating contacts.

Aircraft Direct-Current Motor

TO ITS LINE of aircraft motors, Alliance Mfg. Co., Alliance, O., has added another new design of a direct-current series motor of larger capacity. The unit operates continuous duty on 13 volts direct-current source at 7.4 amperes, delivering a full 1/12-horsepower at 7500 revo-



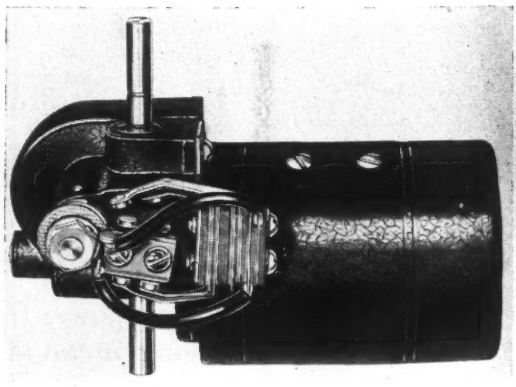
lutions per minute. Of approved aircraft design, the motor is light in weight and sturdy in construction. Overall measurements, less the ¼-inch diameter shaft extension, are: 4 5/16 inches in length, 2¾ inches in diameter. Weight is 3½ pounds. Low temperature rise permits operation under high ambient temperatures. This basic design can be modified to meet other volume applications with either shunt or series windings for desired voltage, current drain and horsepower output up to 1/10 consistent with speed and duty cycle. The motor has a totally enclosed, ball-bearing construction.

Clear Insulating Varnish

SYNTHITE PG-4 clear baking varnish has recently been added to the line of insulating varnishes produced by John C. Dolph Co., 168 Emmett street, Newark 5, N. J. Applied by means of vacuum impregnation, the insulating varnish will not throw out or resoften at high temperatures. Degree of hardness can be controlled by alternating baking time and temperature. Although the varnish solidifies in a relatively short time, a longer bake will produce a finish extremely hard. It is adaptable for use on modern types of polyvinyl acetal coatings of magnet wire, and also on glass insulation because of its heat-dissipating properties. Suitable for other types of Class B insulation as well as textile tapes, the varnish resists acids and alkalies. Applicable to all types of electrical units, large or small, Synthite PB-4 will bake out in 4 to 8 hours at a temperature ranging between 250 and 275 degrees Fahr.

Gear Unit Prevents Motor Overrun

PERMITTING QUICK stopping without motor overrunning is a feature of a new gear unit recently developed by Electric Motor Corp., Racine, Wis. It stops the motor almost instantly, preventing overrun usually experienced in braking electric power-driven devices. The gear unit, known as Model B-1, obtains its quick stopping action

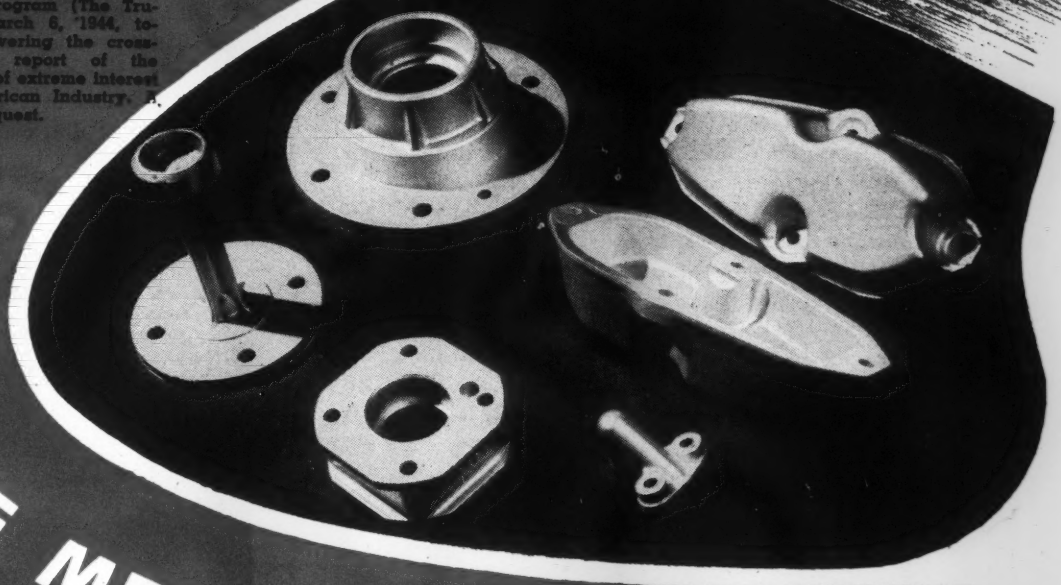


by means of a brake which applies itself in either direction of rotation, or the reversibility of the motor to which it is applied. It is available for mounting on the company's line of fractional horsepower motors, and is already in use on war equipment. It will lend itself to many peacetime applications where instant stopping without overrun is important.

Sensitive Power Multipole Relays

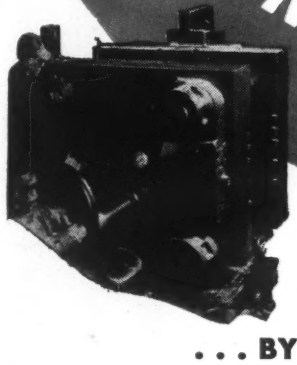
DESIGNED FOR electronic circuits which require small multipole relays, the new Type 27 relay recently developed by G-M Laboratories Inc., 4314 North Knox avenue, Chicago 41, is a small ruggedly constructed unit. It has a

DOWMETAL *magnesium products*



Available—to everyone interested: "Dow and Magnesium"—a booklet covering the statement filed by The Dow Chemical Company with the Special Committee of the U. S. Senate investigating the National Defense Program (The Truman Committee) on March 6, 1944, together with extracts covering the cross-examination and the report of the Committee. This book is of extreme interest and importance to American Industry. A copy will be sent on request.

THE METAL OF MOTION



ANOTHER DOW SERVICE . . . DIE CASTINGS
. . . BY AMERICA'S LEADING MAGNESIUM PRODUCER AND FABRICATOR

• As the pioneer producers of Dowmetal Magnesium Alloys, Dow developed through years of research, a technique in parts production that helped America get a head start on war necessities. Diecasting of magnesium alloys in Dow's own shops today is helping speed us on to victory.

The virtues of high speed, low cost quantity production are enhanced by the decrease in machining necessary—the dimensional accuracy—the excellent surface finish and the weight saving of Dowmetal die castings. Whether for use on present parts or for those still in the print stage Dowmetal Magnesium Alloys die cast by Dow are ready to go to work for you NOW.

MAGNESIUM DIVISION—THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

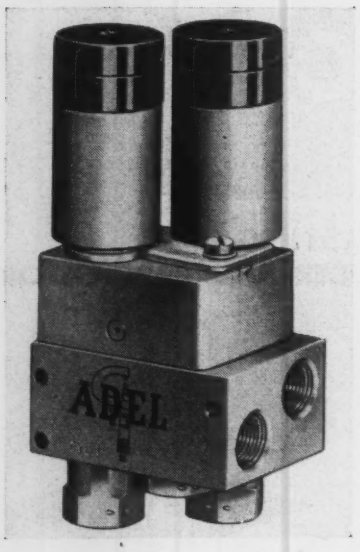
New York • Boston • Philadelphia • Washington • Cleveland • Detroit • Chicago • St. Louis
Houston • San Francisco • Los Angeles • Seattle

high contact capacity in relation to its size, making it ideal for use in aircraft and mobile equipment where vibration is encountered. A feature of its design is the permanence of adjustment of the contact blades. Each blade is shimmed to the correct adjustment which does away with bending of metal parts and thus retains the original metal structure. Size of the 1, 2 and 3-pole relays is approximately 1⅝ x 1 11/16 x 2 inches high. Five-pole relays are 2 x 2½ x 2⅛ inches high. Weight is 4½ to 6½ ounces. Vibration and acceleration is 10*g*. Contact capacity is up to 10 amperes, depending on available power and on coil and circuit characteristics. Contact pressure is 30 to 50 grams.

Coated Aluminum-Bronze Electrode

ANNOUNCED BY The Air Reduction Sales Co., New York, is a new coated aluminum-bronze electrode, AIRCO No. 100. This high-tensile electrode is of the shielded-arc type, and can be used also as a filler rod in carbon arc-welding. Welding deposits of good strength and ductility, combined with resistance to corrosion, are obtainable. The No. 100 electrode has a universal application in welding of most bronzes, malleable and cast iron or steel. In addition it has other applications for which it is suited, such as welding manganese bronze conforming to Federal Specifications QQ-B-726b, or Navy Specifications 49-B-3e for marine propellers and other parts where great strength, ductility and corrosion resistance are requirements. The electrode can also weld dissimilar metals, such as cast iron to brass, steel to malleable iron, or join any two metals which are weldable with aluminum-bronze.

Four-Way Hydraulic Selector Valve



SOLENOID-OPERATED, the new four-way hydraulic selector valve introduced by Adel Precision Products Corp., Burbank, Calif., offers advantages of light weight, greatly accelerated action and low-current consumption. The new valve is designed for aircraft installations located some distance from the flight station such as bomb bay doors, landing gear, wing flaps, etc., where its use reduces length of hydraulic lines and effects weight savings. Dimensions are 2⅝ x 2⅞ x 7 3/16 inches, and weight is 4.1 pounds. Current of 12 amperes at moment of impulse automatically drops at completion of stroke to holding pull of only .2 amperes at 24 volts direct-current. Body is fabricated from dural bar stock. Valve has steel poppets with replaceable steel seats. Electrical connections are provided for either 2-wire or 1-wire and ground circuits, and terminal posts are protected by plastic caps. The valve withstands both continuous duty and rapid cycling, and operates at pressures up to 1500 pounds per square inch.

Electronic Time-Delay Switch

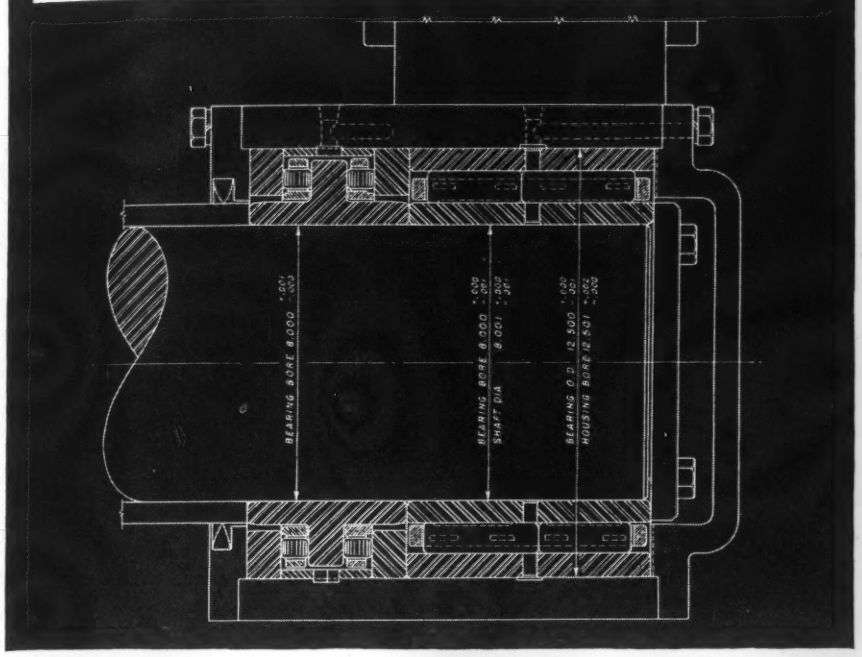
CAPABLE OF operating from power-supply sources having any frequency from 25 to 2000 cycles per second, Type RA-1335-S electronic switches of Richardson-Allen Corp., 15 West Twentieth street, New York 11, provide fixed time delays over a wide range. Units contain a selenium rectifier, two oil-impregnated paper-dielectric capacitors, two vitreous-enamel wire-wound power resistors, two insulated ½-watt carbon resistors, two aircraft-type relays and two standard cold-cathode type gaseous tubes. All parts are moistureproofed for tropical use, and wiring is glass insulated. A typical unit of 400 cycles meets AN requirements and operates within 5 per cent of the rated 20

seconds time-delay when energized by power supplies turning out between 100 and 135 volts at frequencies between 350 and 450 cycles per second, at temperatures ranging between 40 and 65 degrees Cent. with up to 95 per cent relative humidity. It withstands 10*g* shock-impact or vibration-acceleration tests, and will meet 200-hour salt-spray requirements. The 400-cycle unit is available with 110 or 220-volt, single-phase, 10 amperes, double make-double-break contacts. A standard connection plug or terminal board is optional. Dimensions of the switch are 5 x 5⅜ x 3¼ inches, and weight is 3¼ pounds. Power required is 10 watts. Flange mounting on 5½ x 3½-inch centers is provided. The switches may be mounted in any position.

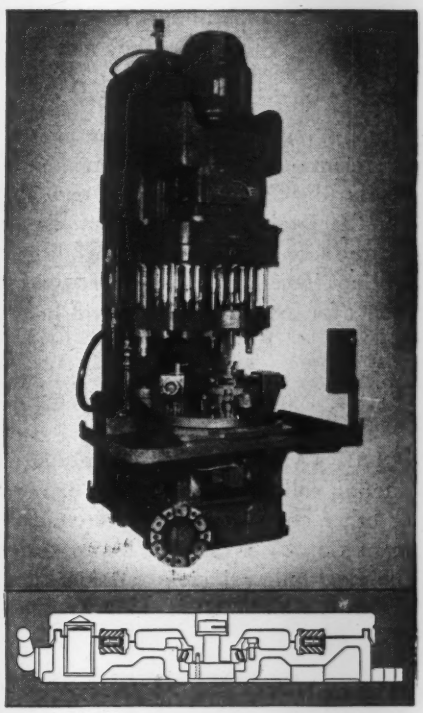
Small-Size Aircraft Hose Clamps

NEW ADDITIONS to the line of Aero-Seal hose clamps manufactured by Aircraft Standard Parts Co., 1711 Nineteenth avenue, Rockford, Ill., are Models M-6 and M-10 for hose sizes from ¼-inch to ¾-inch inclusive. The M-6 is designed for ¼, ⅜, and ½-inch hose, while the M-10 is for ⅝ and ¾-inch hose. By using an extra take-up in the

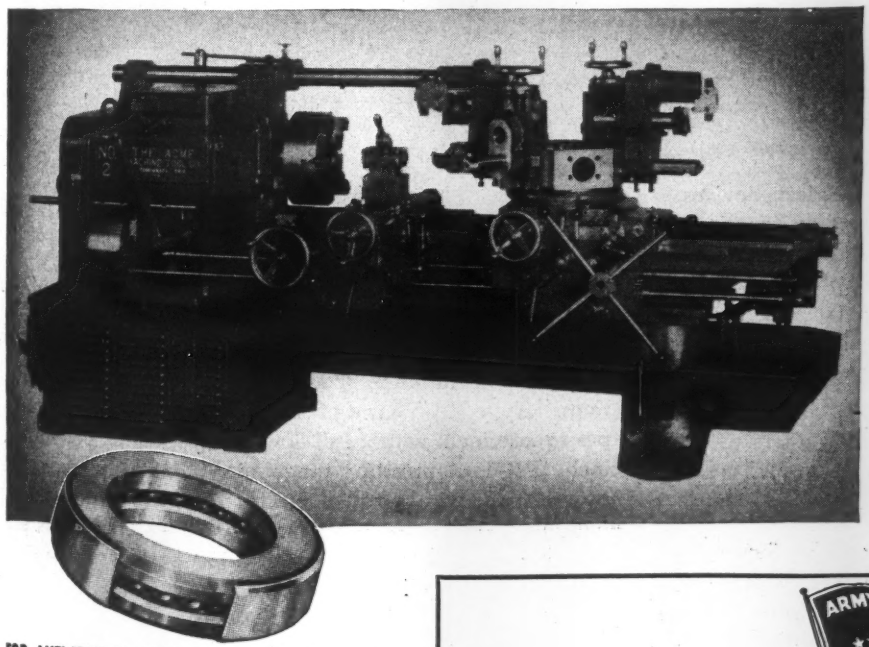
IN THE NEWS
WITH TORRINGTON BEARINGS



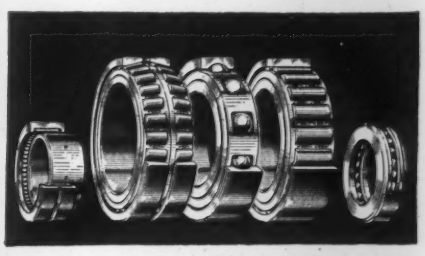
270,000 POUNDS RADIAL LOAD and 168,000 pounds thrust load is the capacity of this compact, 12.5" O.D. Torrington Mill Type Bearing designed by the Company's Bantam Bearings Division to carry the work rolls of a new design axle-type rolling mill in the steel industry. This is another interesting example of the ability of Torrington engineers to design and build anti-friction bearings to meet new and specialized requirements.



MULTIPLE STATION DRILL PRESS, built by Snyder Tool & Engineering Company, uses large Torrington Roller Thrust Bearings to provide anti-friction operation for the rotary table and insure sturdy support to the "work." Bearing, as shown in cross-section, is supplied in three sizes to meet the requirements for both hand and power indexed tables.



FOR ANTI-FRICTION OPERATION on the long and cross feed shafts of this Universal "Cincinnati Acme" Turret Lathe, built by The Acme Machine Tool Company, four Torrington banded Ball Thrust Bearings are employed in each apron. This type of Ball Thrust Bearing as shown in inset is supplied by Torrington's Bantam Bearings Division in a standard range of sizes from ½" to 3½" I.D.



THE COMPLETE TORRINGTON-BANTAM LINE includes every major type of anti-friction bearing—straight roller, tapered roller, Needle and Ball. You will find the experienced assistance of Torrington engineers helpful in selecting the *right* bearing for any anti-friction bearing problem. For today's requirements or assistance in laying out your postwar designs—TURN TO TORRINGTON!

ARMY ★★★ E ★★★ NAVY

TORRINGTON BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

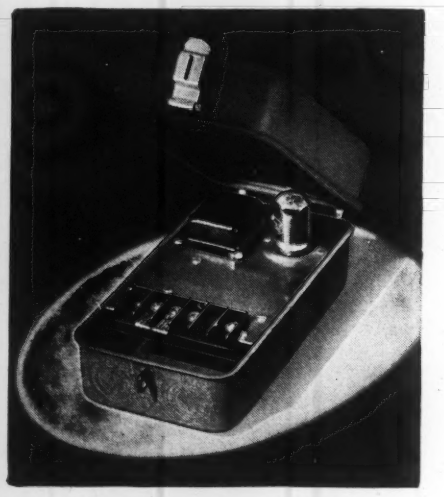
THE TORRINGTON COMPANY · BANTAM BEARINGS DIVISION

SOUTH BEND 21, INDIANA

band, the M-10 can also be used on all five sizes of hose from ¼ to ¾-inch inside diameter. This feature of take-up gives the clamps a wide clamping range. The band is a spring steel strip perforated to correspond with a worm thumb-screw which provides rapid action in tightening the clamp. Since perforations in the band extend for nearly 3½ inches, the clamp may be taken up a full inch (in the larger sizes) on diameter. The clamps do not require lock wire, and as proved on severe vibration tests, will not loosen. They meet new Army and Navy requirements for extra large diametral take-up.

Electronic Level Control

MAINTAINING a level of any liquid or electrically conducting solid within an open or closed tank, bin, hopper or other container, the level control of Trimount Instrument Co., 37 West Van Buren street, Chicago 5, utilizes the electronic principle. It indicates the level by signals or can be installed to operate solenoid or motor-driven



valves, pumps, lights, bells or other electrical devices. The control has no chemical or other effect on liquids or solids being controlled and can be installed in evaporators, freezers, boilers, or other containers involving extreme temperatures. It can control levels of metal chips, acids, brines, chemicals, oil, water and other substances. Various combinations of single and double-electrode installations are available.

Plastic Insulating Tubing and Wire

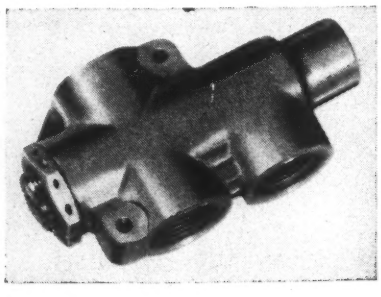
PLASTIC INSULATING parts produced by Suprenant Electrical Insulation Co., 84 Purchase street, Boston 10, are furnished in numerous forms in twenty formulations of tubing and various sizes of wire. The material is known as Surco American. Parts made of it have a dielectric strength averaging 1500 volts per mil thickness. Its mechanical strength is such that it will withstand the exacting demands of various war equipment. Flexibility is good. Temperature endurance is from 295 degrees Fahr. to —80 degrees Fahr. Thickness of the tubing is from .005 to 2 inches inside diameter, and it is available in all lengths and colors. The wire is furnished in continuous lengths in sizes No. 12 to 48 A.W.G. Additional characteristics of the material include those of nonaging, nonflammable, moisture, acid, alkali and hot-oil resistance, and weather resistance.

Small Induction Motor

LATEST ADDITION to the line of 400-cycle equipment of Eastern Air Devices Inc., 585 Dean street, Brooklyn 17, is a small 115-volt induction motor which may be used for general applications requiring 1/50-horsepower continuous duty at 7200 revoltions per minute. Of light weight and small size, the motor has high efficiency and power output. Length is 2 29/32 inches, diameter 1 15/16 inches, and weight 15 ounces. It is cooled by a self-contained fan. The motor has proved useful in driving small blowers. It is obtainable also in either the three-phase or single-phase capacitor type.

Adjustable Pressure Relief Valve

PARTICULARLY adapted to high-pressure systems in aircraft hydraulics, an adjustable pressure relief valve has been developed by American Screw Products, 7000 Avalon boulevard, Los Angeles. Body of the valve is aluminum forging with inner casing of stainless steel, giving long life and smooth operation with maximum flow. The dashpot eliminates vibration and chattering when



pressure is balanced against the spring. Sealing is by AN 62 27 packing rings. The valves will operate satisfactorily in temperatures from —65 to 165 degrees Fahr. and are available in three sizes with the following specifications: Type VR-5 has a pressure range of 300-800 pounds per square inch, with a full flow at 575 pounds per square inch; VR-6, a pressure range of 700-1300 pounds per square inch, with a full flow at 1350 pounds per square inch; and VR-7, a pressure range of 700-1300 pounds per square inch, with a full flow at 1350 pounds per square inch.

Pressure Control Switch

OF SINGLE-POLE construction, the new pressure control switch of Hercules Electric & Mfg. Co. Inc., 2416 Atlantic avenue, Brooklyn 33, is available with normally closed, normally open or double-throw contact arrangement. It is rated at 10 amperes, 125 volts and 2 amperes,

LUMARITH* SAVES WEIGHT

Lumarith gives the aircraft designer an effective means for reducing airplane weight. Lumarith, used directly or in combination with metal can save as much as 50% of the weight of light alloys. Furthermore, Lumarith is comfortable to the touch in coldest weather—has surface permanence regardless of color or degree of transparency—and is a safe electrical insulator.

Injection molded by Cruver Mfg. Co.

MACHETE WITH THE STEERING WHEEL GRIP

Toughness, that has made Lumarith plastics the first choice material for steering and control wheels, gets a shakedown test on this jungle road builder. In this application, Lumarith has to take the concentrated punishment of moisture, heat and hard usage. Injection molded over the steel blade, Lumarith must hold fast under difficult conditions.

For aircraft and automotive control wheels, grips, railings, cable pulleys and brackets, the combination of Lumarith and metal disposes of problems of strength and structure, and, at the same time provides for hand comfort and surface permanence.

The technical service division of Celanese Celluloid Corporation has accumulated data of interest to aviation manufacturers and automotive designers. Your inquiries concerning the full range of Lumarith plastics—their properties and applications—are invited. Celanese Celluloid Corporation, The First Name in Plastics, *a division of Celanese Corporation of America, 180 Madison Avenue, New York City 16.*

*Reg. U. S. Pat. Off.

Lumarith* *A Celanese* Plastic*

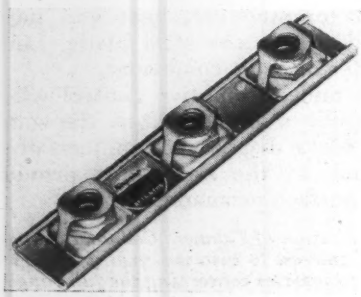
TUNE IN Celanese* Hour—*"Great Moments In Music"*—Columbia Network, Wednesdays, 10 P.M., E. W. T.

600 volts, alternating current. The control element of the switch is a pressure gage of the direct-action type. This gage is designed to withstand shock loads on all kinds of "surging" lines. It maintains its accuracy over a long period of time and is not affected by overloads. Easily readable scales are provided for adjusting cutout and differential. Pressure connection is ¼-inch standard pipe tap, and the L-connection is provided for ¾-inch conduit. Mounted on a solid base of cold-rolled steel with two 9/16-inch diameter mounting holes, the switch is covered by a 14-gage sheet-metal housing with removable front.

A plexiglas window permits observation of the gage. The switch is for solenoid-operated valves, automatic controlling of operating cycles on hydraulic machines, controlling of pumps or compressors, and operating and safety controls in chemical and oil industries.

Gang Channel Announced

FOR USE IN aircraft, marine and ordnance equipment, a new gang channel is announced by Kaynar Mfg. Co., 820 East Sixteenth street, Los Angeles 21. Known as the "Click" gang channel because of the removable nut and bolt retainer, the unit offers such advantages as easy removability using any hexagon stop nuts or bolts, and high torque value. The gang channels consist of retainer plates and retainer springs, both of cadmium-plated, tempered steel, and an ST aluminum alloy channel for light weight. According to the company, in recent torque tests on the ¼-inch aluminum gang channel as much as 265 inch-pounds was attached, this being accomplished through the use of retainer plates having a 100 per cent bearing surface against the channel sides. They are now available in all standard sizes, including straight and curved sections.

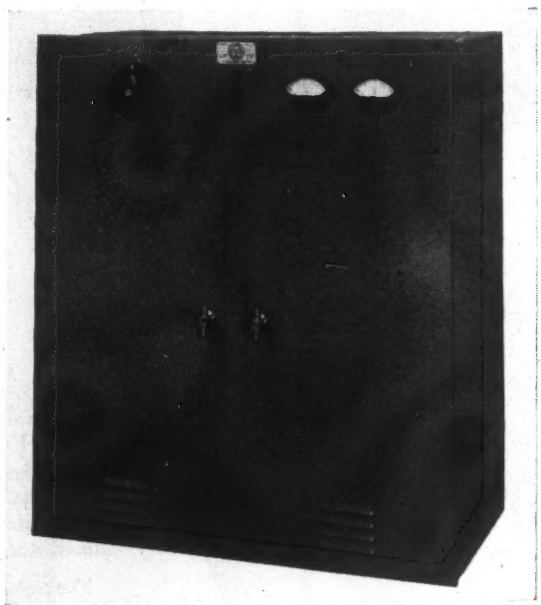


Air-Drying Insulating Varnish

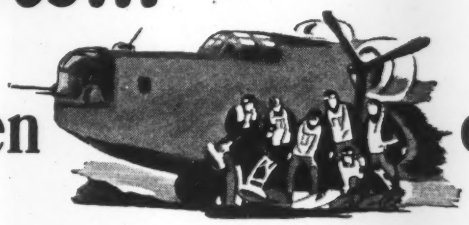
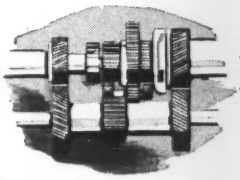
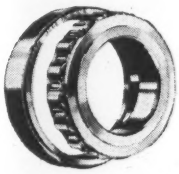
DESIGNED FOR use in electrical equipment, a group of air-drying, insulating varnishes has been announced by The Sterling Varnish Co., 146 Ohio River boulevard, Haysville, Pa. Known as "Speedairbonds", the varnishes dry quickly to a smooth, glossy finish, and are oilproof and water, acid and alkali-resistant. Possessing high dielectric qualities, the finish is flexible and has a long life. It offers protection and insulation under adverse circumstances and atmospheric conditions. This air-drying insulating varnish can easily be applied by brushing, dipping or spraying.

Electronic Motor Controls

ELECTRONIC MOTOR controls in large sizes are being furnished by Electron Equipment Corp., 917 Meridian street, South Pasadena, Calif. The control shown in the accompanying illustration is a 50-horsepower size, and gives variable speed adjustment to direct-current motors from a three-phase alternating-current line. This model is also available in sizes from 1 horsepower to 250 horsepower, and can be operated from any alternating-current line of 50 or 60 cycles. Speed ratio is up to 20 to 1 at constant torque, and higher at constant horsepower applications; all stepless. Any ordinary shunt-wound direct-current motor may be used. An electronic transformer is used in the new controls which makes possible speed control with the use of simple gas diode tubes and simple circuits. Use of grid-controlled tubes is unnecessary. Preset speeds with current limited acceleration, reversing, dynamic braking, inching, plugging, etc., may be specified. The unit may be used for steel mill drives, oil well machinery, veneer lathes, rubber mills and other industrial machines.

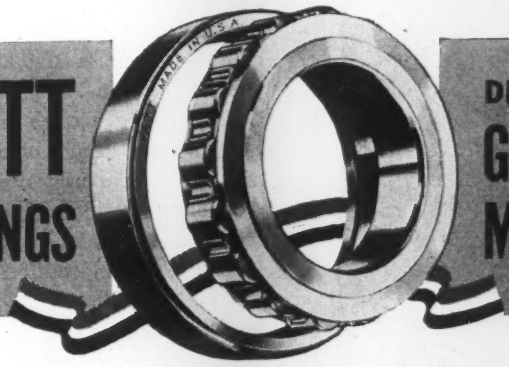


With their lives...

our fighting men  depend on the micro-inch accuracy and unfailing strength of vital parts  in planes, ships, tanks and guns. Prominent among these parts are millions of  Hyatt Roller Bearings... guarding against friction and power losses... guarding against losses of things that are precious to every American

HYATT ROLLER BEARINGS SERVE SILENTLY, ACCURATELY, EFFORTLESSLY
WHEREVER GEARS, SHAFTS, AND WHEELS TURN

HYATT BEARINGS

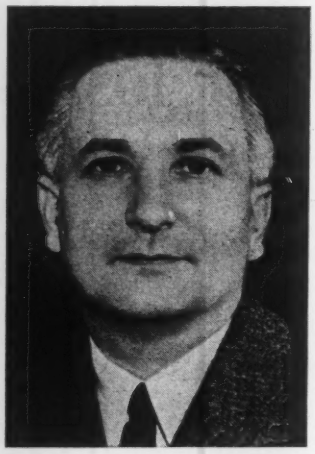


DIVISION OF GENERAL MOTORS

HYATT BEARINGS DIVISION · GENERAL MOTORS CORPORATION · HARRISON, NEW JERSEY

Men of Machines

ADVANCEMENT of Harold J. Siekmann to the position of chief engineer has been announced by R. K. LeBlond Machine Tool Co., Cincinnati. He succeeds William F. Groene, formerly vice president and chief engineer, who recently retired. Mr. Siekmann joined the LeBlond organization in 1910, and after a four-year apprenticeship was placed in the engineering department. He remained in this department since that time, with the exception of an interval in 1917 and 1918 when he was in government service, and also during several years when he was in the company's sales department in California and Cleveland. Mr. Siekmann had been closely associated with Mr. Groene (who has been responsible for many developments in machine tools and holds over one hundred and thirty patents jointly and in his own name) in the development of the organization's machines, being co-inventor of many of the patents covering LeBlond features. Being selected for the position previously filled by a man who was capable of developing a reputation for the design and improvement of machines for crankshafts, is in itself a recognition of his capabilities.



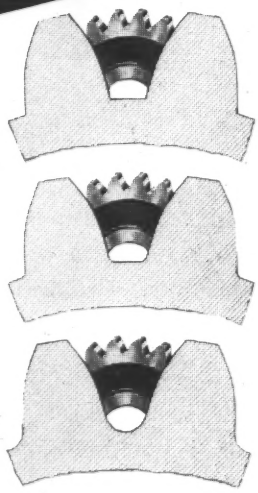
AWARD OF the Gold medal for 1944 given by the American Institute of Chemists will be made to Willard Henry Dow "who found out how to make enough magnesium to produce thousands of fighting airplanes, and enough styrene to supply our needs for synthetic rubber". The medal is to be presented at the annual meeting of the Institute. Dr. Dow is president of The Dow Chemical Co., Midland, Mich., and is regarded as one of the foremost leaders of research. Born at the scene of his present activities, Midland, Mich., in 1897, Dr. Dow's entire training is calculated to fit him for his present position. In 1919 he graduated with a bachelor of science degree in chemical engineering from the University of Michigan, and went to work for Dow Chemical the same year. In three years he became a director and general manager of the company. Upon the death of his father, Dr. Herbert Henry Dow, in 1930 he became president and general manager. He now also is head of a number of associated companies which have put into practical operation many of the Dow company's inventions and processes. Dr. Dow is a member of the American Institute of Chemical Engineers.

AT THE RESEARCH Division of United Shoe Machinery Corp., Beverly, Mass., J. F. Downie Smith has recently been appointed head of the engineering department. For three years prior to his appointment he was chief engineer in the aircraft section. Before becoming connected with United Shoe in 1940 he had been associated for four years with Edward G. Budd Mfg. Co. as executive engineer of research and development, responsible for design of air-conditioning systems, truck design, and automobile and railcar improvements generally.

Born in Linlithgow, Scotland, in 1902, Dr. Smith received his training at Royal Technical College and Glasgow university. While at the latter he served as an apprentice tool and machine designer with Albion Motor Car Co. Ltd., Scotland. In 1924 he became assistant professor of experimental engineering at Georgia School of Technology and taught thermodynamics, power plant engineering, hydraulics and experimental laboratory studies. Two years later at Virginia Polytechnic institute he served as assistant pro-

GEARGRIND

ACCURACY—FINISH—SPEED



DEFINITE CONTROL OF ROOTS

GEARGRIND formed wheel trimmers and wheel trueing devices insure whatever root profiles your design calls for —straight roots or definite radius fillets as well as full radius roots giving absolute line continuity for carrying maximum loads.

The GEARGRIND method of Formed Wheel Grinding is demanded by many leading engineers because it insures volume production of finely finished, highly accurate parts that require a negligible amount of reworking.

Investigate GEARGRIND Machines at once, if your program calls for accuracy, fine finish and speed in the production of external and internal gears, external and internal involute splines, straight splines, serrations and racks.

Standard requirements are fully met by standard GEARGRIND Machines, but if you have a tough job requiring a special machine, we are in position to design and build it for you. Full information is given in our general catalog.

The GEAR GRINDING MACHINE COMPANY

DETROIT 11, MICH. U.S.A.

fessor of engineering drawing, and taught drawing and descriptive geometry. He then moved on to the Harvard Graduate School of Engineering. Here from 1928 to 1936 he was assistant, National Research Fellow, and faculty instructor in mechanical engineering. He taught heat transfer, advanced calculus, statistical methods in engineering and physical requirements. Leaving Harvard in 1936 he joined Edward G. Budd Mfg. Co., where he remained until becoming associated with United Shoe Machinery Corp. In his new position as head of the engineering department at the latter company he will be in charge of engineering involved in the design of fire control equipment and shoe machinery.

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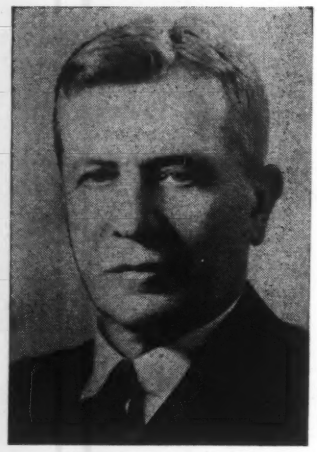


FOR "ADVANCING the oxy-acetylene processes through metallurgical research, and for leadership in welding engineering education," Charles Ellison MacQuigg, dean of engineering at Ohio State university, was recently presented the James Turner Morehead Medal of the International Acetylene association. In addition to his duties as dean of engineering, Mr. MacQuigg is also head of the engineering experiment station, director of the university's research foundation, member of the War Metallurgy committee of the National Academy of Sciences, and chairman of the executive committee of the Society for the Promotion of Engineering Education. In his over thirty years' experience in numerous types of metallurgical activities, he has had a part in extensive research and development work on welds and materials for welding. Pioneer work under his direction, specifically in developing high-strength steel, bronze, and stainless steel rods for oxy-acetylene welding, has served as a foundation for many recent researches in this field. Mr. MacQuigg was instrumental in developing and establishing at the Ohio university the first complete curriculum in welding engineering. Prior to his appointment as dean of the college of engineering at Ohio State in 1938, he was manager of Union Carbide & Carbon Research Laboratories Inc. Before this he had for five years been head of the department of metallurgy at Pennsylvania State College.

♦

HOWARD F. MURPHY has recently been made chief engineer of U. S. Machine Corp., Lebanon, Ind. Previously he had been design engineer for the company.

♦

HAROLD A. KIBITZ, formerly chief designer at J. W. Droll Co., Chicago, has become chief engineer.

♦

ROY HARTMAN has become a partner and chief engineer of Electronic Instrument Co., Tiffin, O.

LEE OLDFIELD has been appointed president of Laboratory Equipment Corp., Mooresville, Ind. Mr. Oldfield previously had been chief engineer of Merz Engineering Co.

♦

W. D. REESE has been appointed manager at International Harvester Co., Chicago.

♦

A. J. TIGGES has been made manager of consulting engineering for all divisions and subsidiaries of Baldwin Locomotive Works, Philadelphia, including locomotive and ordnance. Mr. Tigges will in addition have charge of engineering of new products and applications relating to postwar plans.

♦

DEAN C. SMITH has become connected with Fairchild Engine & Airplane Corp., Farmingdale, L. I., N. Y. in charge of development. He left Curtiss-Wright Corp. to take this position.

♦

J. S. F. CARTER, chief design engineer of the Cherokee Ordnance Works, has been appointed engineer in charge of design and engineering service for the process division of S. K. Hicks & Son Co. Inc., Boston.

♦

WILLIAM S. WHEELER, who started with the Pennsylvania Engineering Works, New Castle, Pa., as draftsman in 1905, has passed through the ranks to his present appointment as president of the company following the retirement of W. H. LEWIS. Previously Mr. Wheeler was vice president and general manager. H. L. MCFEATERS is the new chief engineer.

♦

HARVEY T. HILL has recently been appointed executive director of the Diesel Engine Manufacturers association, with headquarters in Chicago.

♦

T. C. KNUDSEN has been made manager and chief engineer of the new Texrope department, recently established by Allis-Chalmers Mfg. Co., Milwaukee.

♦

K. L. MAIER is the new chief product engineer of Brown Instrument Co. division of Minneapolis Honeywell Regulator Co., Philadelphia.

♦

ROBERT M. GAYLOR, president of Ingersoll Milling Machine Co., Rockford, Ill., has been appointed president of the National Association of Manufacturers.

♦

G. BRIGGS WEAVER, chief design engineer, has been made a director of Indian Motorcycle Co., Springfield, Mass.

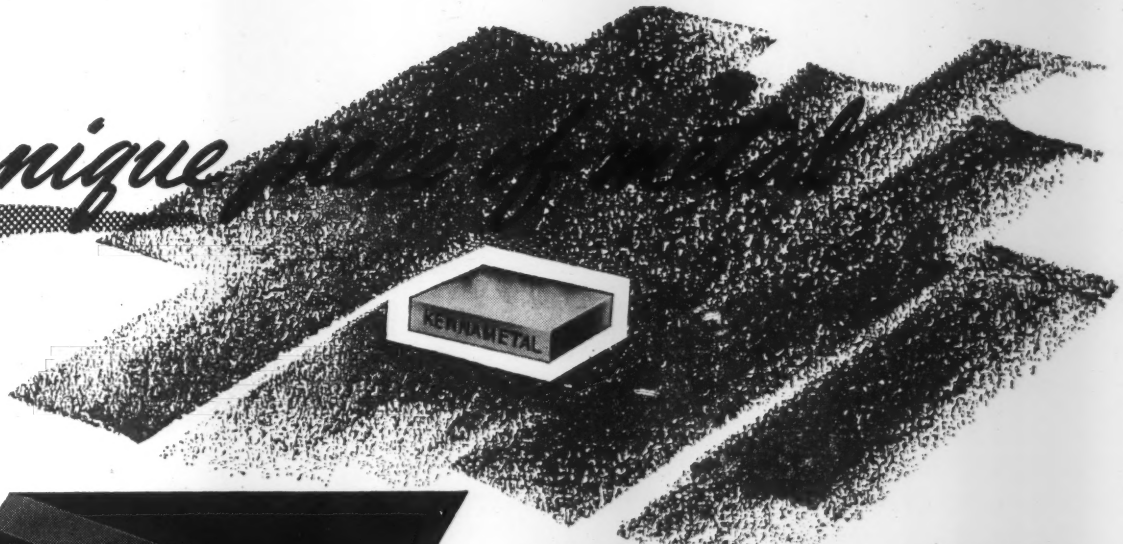
♦

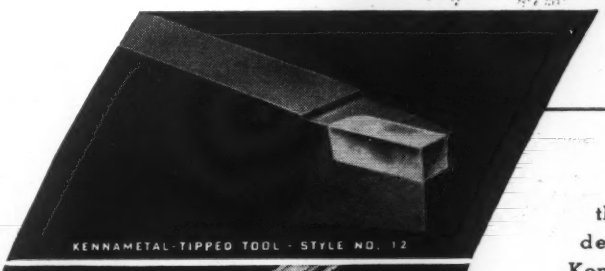
FRED C. HANDREN has been named chief engineer of Progressive Welder Co., Detroit.

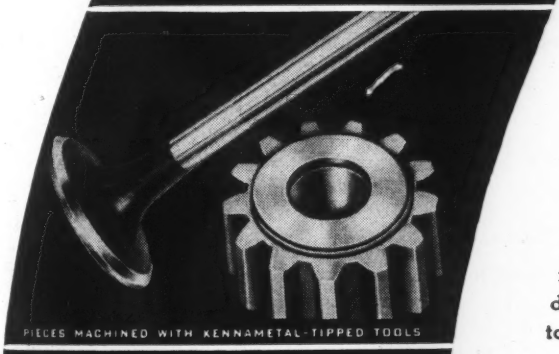
♦

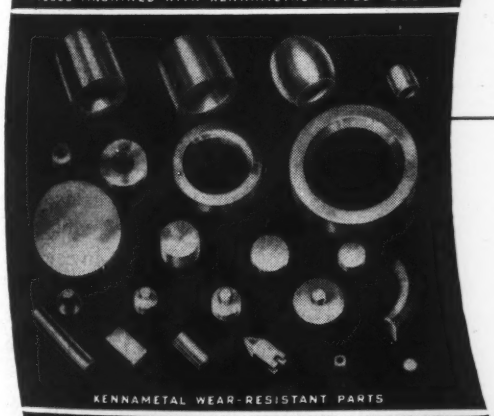
DR. IRVING LANGMUIR, associate director of the General Electric Research Laboratory, has been awarded the Faraday medal of the Institution of Electrical Engineers in London, given for world-wide services to electric science and engineering.

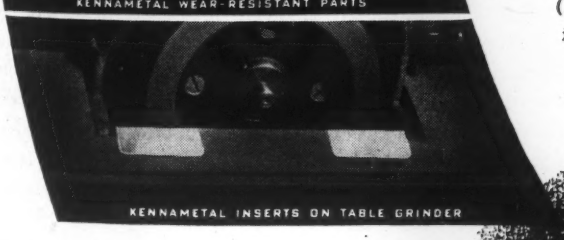
This unique material




KENNAMETAL-TIPPED TOOL - STYLE NO. 12


PIECES MACHINED WITH KENNAMETAL-TIPPED TOOLS


KENNAMETAL WEAR-RESISTANT PARTS


KENNAMETAL INSERTS ON TABLE GRINDER

SOLVES MACHINING PROBLEMS..

"Too tough to machine, too hard to work"—time and again these words by production men sounded the death knell of designers' specifications. That is, until the discovery of Kennametal, the unique cemented carbide composition whose amazing hardness immediately established it as a tool material that makes practically any metal easy to cut. Kennametal-tipped tools swept away traditional machining limitations—making practical the cutting, boring, and milling of materials up to 550 Brinell at speeds that multiply output, and substantially reduce production time and costs. This application of Kennametal is a tremendous aid to better machine design, since it permits the use of tough, hard, lighter-weight parts instead of cumbersome components that were incorporated primarily because of their "machinability." Write for our Catalog 43-C that describes Kennametal tools. Study it with your production men—learn how to use the most advanced metal-cutting technique to improve your designs.

IMPROVES PRODUCT PERFORMANCE . . . .

Incredibly hard Kennametal (80.6 on the Rockwell C scale) delights designers who have been plagued by machine failure caused by abrasive or corrosive wear. Kennametal is up to 250 times as wear-resisting as steel. Its use at strategic points nullifies effects of friction and corrosion, assuring lasting precision performance. Complete Kennametal parts can be manufactured by us for use in your machines. Or—inserts of Kennametal can be easily incorporated into wear-areas. They are supplied . . . (1) accurately formed to desired shape, for brazing and finish grinding in your shop . . . (2) mounted on parts furnished by you, after which finishing is done either by you or by us . . . (3) embodied in complete parts produced by us. Don't let "wear" worry you—write us about your problem, and we'll show you how Kennametal can solve it.

KENNAMETAL

SUPERIOR CEMENTED CARBIDES

KENNAMETAL Inc., 146 LLOYD AVE., LATROBE, PA.

ASSETS to a BOOKCASE

Handbook on Designing for Quantity Production

Edited by Herbert Chase; published by McGraw-Hill Book Co. Inc., New York; 517 *pages,* 5⅛ *by* 8¼ *inches, clothbound; available through* MACHINE DESIGN, $5.00 *postpaid.*

In the design of parts intended for mass production, the designer has his choice of utilizing a number of processes such as stamping, sand and die casting, screw machine, die forging, heading, and plastic molding. Quite often, because his particular experience may have been with only a few of these high-production processes, he tends to overlook the possibilities offered by the others and the mechanisms he designs suffer in quality and economy accordingly. Thus it is imperative that the man responsible for putting machines on paper be equipped with at least a general knowledge of the processes themselves and know how to design to take full advantage of the economies offered as well as to avoid types of construction that increase cost unnecessarily.

The procedure employed in preparing this book is commendable. It has been written, not by one man, but rather by a group of men each an authority in the field of which he writes. The content includes valuable suggestions on the design of parts for production via die and sand casting, screw machine, stamping, die forging, hot and cold heading, and plastic molding. Part II in particular is recommended. It presents the factors which influence choice between die and sand casting, permanent-mold and die casting, die casting and stamping, etc.

□ □ □

Psychology of Supervising the Working Woman

By Dr. Donald A. Laird, industrial consultant; published by McGraw-Hill Book Co. Inc., New York; 202 *pages* 5$\frac{5}{16}$ *by* 7⅞ *inches, clothbound; available through* MACHINE DESIGN, $2.00 *postpaid.*

It would seem to be a safe bet that there will be many more women in industry after the war than there were before, when one out of every five wage earners was a woman. Today, we have women engineers, draftsmen, blacksmiths, riveters, deep-sea divers, sea captains, airplane pilots, and even night-club bouncers!

That's the trend—more women in industry. Perhaps you feel somewhat like the Turk who, asked by an American traveler why he had given up his harem, sagaciously replied: "I long ago discovered that one woman is enough for any man—and sometimes that is too much." No matter, for many of the gentler sex who now work by your side in the drafting room and research laboratory will stay on after the war.

There can be little question but that working women require different handling from that accorded to men and, because this is so, the problems encountered today in supervising help are more complex than in the past. Fortunately, men such as Dr. Laird, the author of this book, have been aware of these problems for some time and have seen fit to conduct studies of the physical and psychological factors involved. This present book, one of a series by the author on psychological aspects in modern living, offers much that should be helpful to the individual engaged in supervising women. A few representative chapters are those dealing with adjusting work to woman's brain power, strength, fatigue characteristics and muscular control. Considerations involving emotion and temperament characteristics are fully discussed, and of particular interest in connection with the design of machines are the chapters dealing with the influence of woman's bone and joint structure on the design of mechanical equipment to be operated by women.

□ □ □

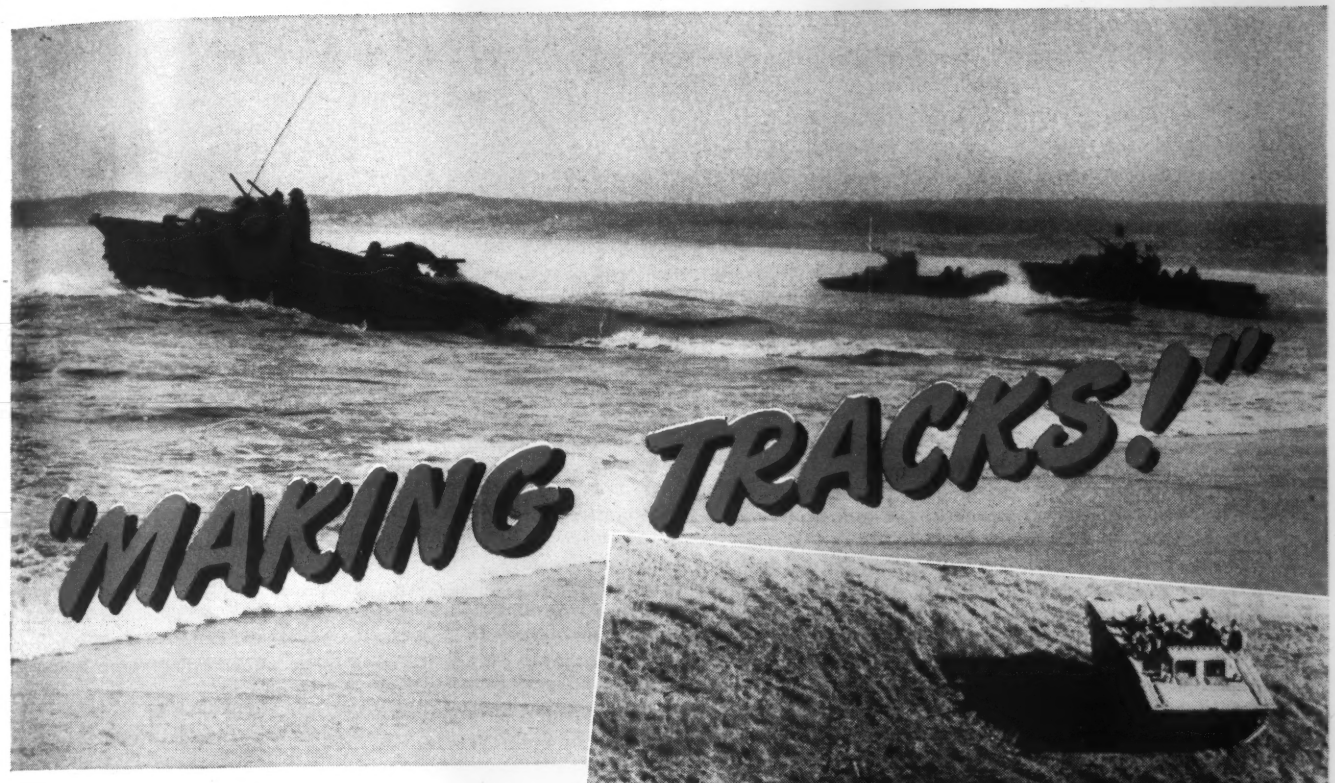
Plastic Working in Presses

By E. V. Crane, Ph.B., M.E.; published by John Wiley & Sons, Inc., 540 *pages,* 5⅜ *by* 8$\frac{5}{16}$ *inches, clothbound; available through* MACHINE DESIGN, $5.00 *postpaid.*

Viewing in retrospect our gigantic automobile industry, now so efficiently engaged in the mass production of aircraft, tanks, army trucks, jeeps, and a hundred other items vital to the successful prosecution of the war, one finds it hard to believe that at the start—not so many years ago—automobiles were sawed, turned, sheared and beaten out, one at a time, without much plant equipment or any special tooling to speak of. One has but to compare the smooth, flowing lines of the modern automobile with the first crude attempts at styling to become cognizant of the truly advanced state of development to which the plastic working of materials has progressed.

Today there is hardly a single mass-produced mechanical item which does not contain at least one part made by stamping, forming or deep drawing. Under the impetus of an all-out war program, operations have been conceived and are being performed on presses which heretofore either were deemed impracticable or never thought of. To take full advantage of the latest developments in the art of plastically working materials, the designer is wise who acquaints himself fully with the possibilities of the processes involved and the merits and limitations peculiar to them.

This book is a good, practical manual on press work. It does not dwell overlong on any particular phase of its subject, yet conveys a clear, comprehensive picture which



Again Morse Experience Comes To The Front

L.V.T. (2) Water Buffaloes constructed by the Food Machinery Corporation have what it takes to forge steadily ahead towards their objective.

Morse, with close to half a century's experience in the building of special and standard silent and roller chain, was called upon to build the special track chains which carry these Water Buffaloes over land and water.

Morse design engineers welcome the tough jobs. Their services are available to those desiring specially developed chains or chain assemblies for conveying, handling or other purposes.

SPROCKETS CHAINS FLEXIBLE COUPLINGS CLUTCHES

MORSE Roller and Silent CHAINS

MORSE CHAIN COMPANY • ITHACA, N.Y. • DETROIT 8, MICH. • A BORG-WARNER INDUSTRY

should help considerably to provide the designer with the substantial background knowledge so important in competent design of mass-produced parts.

After a chapter devoted to an overall picture of metal press-working, the author discusses essential metallurgy, shearing, bending, expanding, contracting, curling, plasticity, drawing, extruding, forging, automatic production etc. The tables giving such information as minimum bend radii for various thicknesses and tempers should prove of particular value as should the numerous illustrations showing methods of drawing, ironing, curling, etc.

□ □ □

Work Methods Manual

By Ralph M. Barnes, professor of industrial engineering and director of personnel, College of Engineering, University of Iowa; published by John Wiley & Sons, Inc., 136 pages, 5⅜ by 8⅛ inches, clothbound; available through MACHINE DESIGN, *$1.75 postpaid.*

Since it is only rarely that an automatic machine does not require the services of a worker to turn it on and off, load it, unload it or adjust it, etc., it is logical that the mechanical units subject to such manual service or manipulation be so located and designed as to permit performance of the required manual functions with as little effort and at as great a speed as possible. Manufacturers of all kinds of production machinery are becoming increasingly aware of the importance of this phase of design. It is a predominant factor in the trend toward greater "automaticity" and foolproof machine control.

Much can be done to diminish the machine operator's work and responsibility through the study of hand and body motions necessary to do a given job. This book, while not directed specifically at the chief engineer or machine designer, nevertheless contains a wealth of information on methods study which may well prove helpful in the design of production machines.

Motions and methods used in performing various manual jobs are analyzed, stressing the importance of locating hand controls close to and directly in front of the operator, holding to a minimum the necessity for the operator to reach and move about, relieving the hands of work which can be done more advantageously by the feet, and establishing sequence of smooth, continuous hand and body motions such as will permit rhythmic performance so necessary to high manual efficiency.

Fourth edition of a comprehensive 479-page handbook "Practical Metallurgy for Engineers" recently has been published by E. F. Houghton & Co. Representing the combined efforts of members of the company's research staff, it covers such phases of the subject as the physics and chemistry of metallurgy, fuels, refractories, ores, manufacture of iron and steel, mechanical and temperature treatments, quenching, grain size and hardenability, etc. It is a substantial contribution to the engineering profession and should prove a worthwhile addition to the technical library. Clothbound, it lists at $3.

BUSINESS AND SALES BRIEFS

ESTABLISHMENT of a sales office in the Chamber of Commerce building, 30 East Broad street, Columbus 15, O., has been announced by Cutler-Hammer Inc., Milwaukee. Russell D. Yoder, sales engineer, has been placed in charge of the new office which will be operated as a branch of the Cincinnati district sales office.

♦

Recently the Cleveland Graphite Bronze Co. celebrated its twenty-fifth anniversary. The present executive managers, Ben F. Hopkins, J. J. McIntyre, James L. Myers and Carl W. Johnson, originally founded the company in 1919.

♦

Harold Van Doren & Associates of Philadelphia and Toledo has merged with Roger L. Nowland, Peter Schladermundt and Katherine B. Gray as a new industrial design partnership. Offices of the firm, to be known as Van Doren, Nowland & Schladermundt, will be located at 10 East Forty-ninth street, New York, 1717 Sansom street, Philadelphia, and 1217 Madison avenue, Toledo.

♦

Leasing of a four-story building at 5109 Germantown avenue, Philadelphia, has been announced by Brown Instrument Co. Electronic control panels for automatic pilots will be produced.

♦

Appointment of Moore Machinery Co., Los Angeles and San Francisco, as special distributors for induction heating and hardening equipment in California, Nevada and Arizona has been announced by Ohio Crankshaft Co., Cleveland.

♦

Since 1937 manager of the Midwest district, William O. Wilson has been made commercial vice president, Worthington Pump & Machinery Corp., Harrison, N. J., and will be responsible for commercial activities in the Midwest district.

♦

National Screw & Mfg. Co., Cleveland, has announced the following appointments: George Ingersoll has been named district sales manager in Cleveland and adjacent territory. S. M. Washabaugh has been made district manager in Philadelphia and E. A. Derby holds the same position in metropolitan New York and New England.

♦

In the Norwood, O., works of Allis-Chalmers Mfg. Co., A. D. Robertson has been named assistant manager of the motor division.

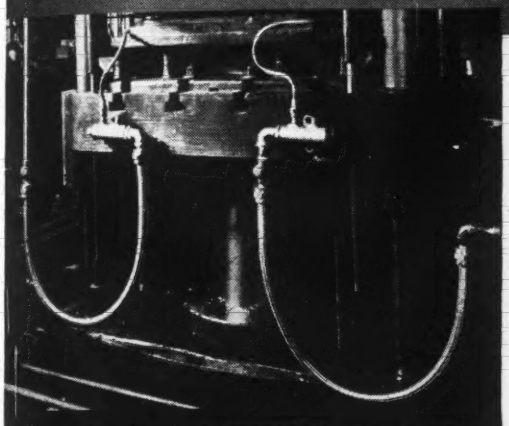
♦

For the past four years manager of the Atlanta branch, Paul B. Means has been appointed manager of the diversified products department, Seiberling Rubber Co. He will make his headquarters at Barberton, O.

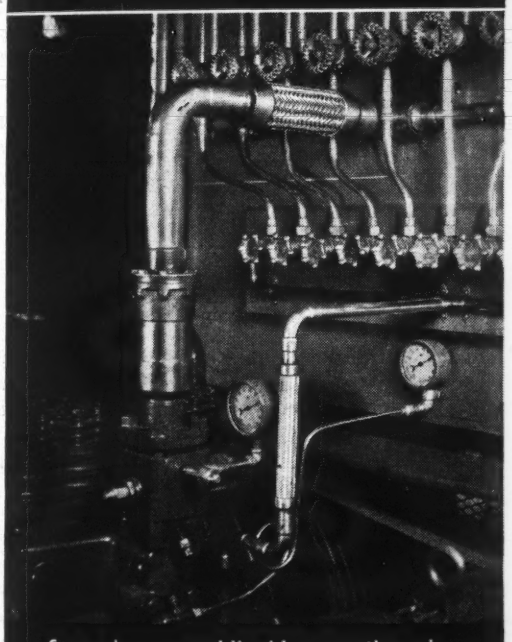
♦

Appointment of W. G. McFadden as district manager of the Chicago office has been announced by Allegheny Ludlum Steel Corp. Mr. McFadden previously had been assistant district sales manager of the same office. He served as acting manager during the absence of P. E. Floyd, sales manager of this district.

SEAMLESS METAL TUBING
...flexible as a blacksnake whip



Conveying steam and connecting moving parts



Conveying gas and liquid, connecting misaligned parts, absorbing vibration

meets a thousand exacting requirements

The tubing is American Seamless Flexible Metal Tubing—the most reliable type of flexible metal conveyor obtainable where *absolute tightness is essential.* Because it is jointless it is, in effect, a flexible pipe.

Applications are practical in literally thousands of places in industry. Typical functions are illustrated on this page:

1. *For conveying steam.*
2. *For conveying liquids and gases.*
3. *For absorbing vibration.*
4. *For connecting misaligned or moving parts.*
5. *For protecting electrical wiring.*

Our technical department is experienced in designing flexible metal assemblies for specific applications. If you have a particular problem, maybe we can be of assistance to you. 44192

AMERICAN METAL HOSE BRANCH
OF THE AMERICAN BRASS COMPANY
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Subsidiary of Anaconda Copper Mining Company
General Offices: Waterbury 88, Connecticut
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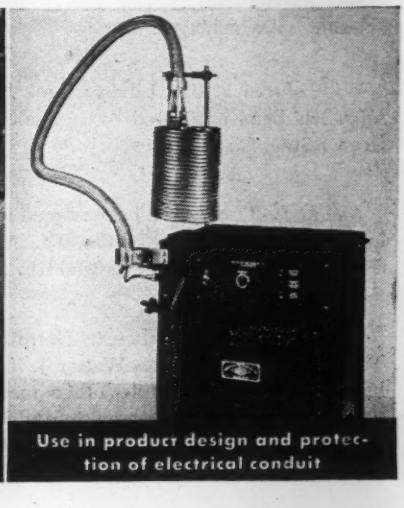
American Metal Hose

Conveying gas and connecting moving parts



Use in product design and protection of electrical conduit

who was with the War Production Board. Mr. Floyd has since been released from WPB and has assumed the position of assistant general manager of sales for the corporation at Brackenridge, Pa.

♦

Succeeding C. R. Walker as Detroit representative, Osborn Mfg. Co., Cleveland, is W. T. Glendinning. Mr. Walker has been put in charge of the northern Ohio territory and George R. Lundberg has been named sales representative in northern Michigan.

♦

Assistant sales manager since 1941, Lyman D. Warner has been made sales manager, Crocker-Wheeler division, Joshua Hendy Iron Works, Ampere, N. J.

♦

Position of assistant to the president of Firth-Sterling Steel Co., McKeesport, Pa., has been given to Bennett S. Chapple Jr. Prior to this appointment he had been connected with Carnegie-Illinois Steel Corp. in various sales capacities.

♦

Having resigned from Universal Plastics Corp., New Brunswick, N. J., Bernard Schiller together with R. D. Werner of R. D. Werner Co. Inc., has formed Ardee Plastics Corp.

♦

Crown Plastics Corp., newly organized by Charles C. Livingston, A. K. Livingston, Emil Ibach and F. J. Hoope, will now be known as Livingston Plastics Corp. The company is located at 1431 West Hubbard street, Chicago 22.

♦

According to a recent announcement by Tube Turns Inc., Louisville, Ky., G. Bronson Philhower has been made sales representative in metropolitan New York and New England.

♦

Formerly with Reilly Tar & Chemical Co., William J. Dunnican has joined Durite Plastics, Inc., Philadelphia, as application engineer.

♦

In addition to his position as general manager, W. A. Moore has been made vice president of Armstrong Tire & Rubber Co., Natchez, Miss.

♦

Having spent fifteen months in the ordnance department, P. L. Dafoe has returned to his former position as sales manager, Central division, Acme Steel Co., Chicago.

♦

Pesco Products Co., Cleveland, a division of Borg-Warner Corp., has announced the appointment of E. S. Moreland as assistant sales manager.

♦

With offices at 525 Liberty Bank building, Buffalo, Jack E. Allen has been appointed district sales representative, Wyckoff Drawn Steel Co., Pittsburgh.

♦

Arthur J. O'Leary has been named assistant manager of sales, Lukens Steel Co., Coatesville, Pa. At the same time George Eshelman has been made assistant to the manager of sales.

♦

Opening of a new office in Detroit has been announced by The Dow Chemical Co. Walter J. Truettner has been named head of the office while other members include Ralph B. Ehlers, in charge of magnesium distribution and service in southeastern Michigan, and Paul M. Jensen, in charge of plastics. In the Los Angeles office K. T. Vangsnes has been appointed head of the Magnesium division at 634 South Spring street. Mr. Vangsnes had been vice president of Magnesium Products Inc., Los Angeles, for the past five years.

♦

Recent announcement has been made by Boonton Molding Co., Boonton, N. J., of the appointment of William T. Stopford as New York representative.

♦

Pierce Plastics, Inc., 116 First street, Bay City, Mich., has been acquired by Visking Corp., Chicago. No major changes in operations are contemplated at present.

♦

Position of district manager in charge of Finkl Steel Products Corp. of California, newly-formed subsidiary of A. Finkl & Sons Co., Chicago, has been given to R. M. Edinger. Previously Mr. Edinger had been connected with R. J. M. Co., Los Angeles. The new subsidiary is located at 900 Santa Fe avenue, Los Angeles.

♦

In the Detroit office Paul W. Butz has been named district manager of sales, Columbia Steel & Shafting Co.

♦

Appointment of Robert A. Campbell as sales manager of the Steel Tube division, Oil City, Pa., has been announced by Talon Inc., New York. Previously Mr. Campbell had been assistant sales manager, Ohio Seamless Tube Co., Shelby, O.

♦

A branch office at 378 Fifth street, San Francisco, has been opened recently by Kennametal Inc., Latrobe, Pa. This office will cover northern and central California.

♦

Succeeding R. J. Seltzer as manager of the Birmingham, Ala., plant of Rheem Mfg. Co. is Erle R. Merrell. Mr. Seltzer has been transferred to the plant in Sparrows Point, Md.

♦

Promotion of William Ray Mau from district manager in the Chicago territory to western sales manager has been announced by Vanadium-Alloys Steel Co. He will continue to make his headquarters in Chicago.

♦

With offices at 100 East Forty-second street, New York, and 7 South Main street, West Hartford 7, Conn., Rudel Machinery Co. Inc. has been appointed sales representative in the New York and Hartford territory for Logansport Machine Co. Inc. In addition to the Texas territory previously assigned, C. G. Wilson Co. has been given the Tulsa, Okla., territory.

♦

Baldwin Locomotive Works, Philadelphia, has announced the appointment of C. E. Kraehn as assistant to V. H. Peterson, vice president in charge of sales activities. Prior to joining the company last year Mr. Kraehn had been connected with General Electric Co. for twenty-four years.

♦

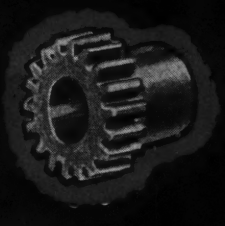
Election of Claude S. Speicher as treasurer to succeed the late Joseph E. Somers has been announced by Somers Brass Co. Mr. Speicher, who will retain the office of vice president, joined the company in 1929 as manager of sales and general manager.

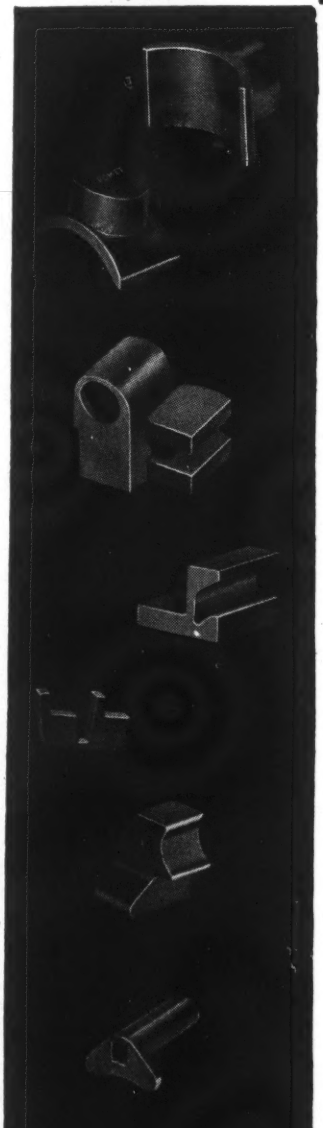
♦

Establishment of sales offices in Philadelphia, New York and Detroit has been announced by Franklin Plastics division, Robinson Industries, Inc., Franklin, Pa. Charles F. Hamilton has been named manager of the Detroit office at 612 Stephenson building. J. M. Waldecker becomes head of the district sales and

POMET POWDER METALLURGY

FROM POWDER
TO PARTS
WITH POMET





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YOU SEE WHAT
POMET CAN DO

TO ± .001" OR CLOSER

. . . *without machining*

Step up production, reduce costs, save materials, save man hours, but hold those tolerances—these are the exacting demands that Pomet is meeting.

Much closer tolerances can be held today than were thought possible a few years ago. In many cases, expensive machining has been entirely eliminated in the manufacture of intricate machine parts by Pomet methods. In all cases, machining is cut down to a point where the saving in cost is very interesting.

A great variety of complicated parts can be produced quickly, accurately and at substantial savings. Gears, pole pieces, cams, brush holders, spline wheels, wire guides, gun sights and triggers are just a few of the many parts that are being turned out in great quantity to rigid specifications.

Many metals and combinations of metals are being used, including brass, bronze, iron, steel, and other ferrous alloys, and aluminum.

Greatly expanded facilities assure even faster production. High technical excellence is being maintained and constantly improved. Manufacturers who wish to keep cost in line with rigid specifications will find the Pomet plant well equipped to take care of quantity orders of a hundred thousand or more parts at a very interesting saving in costs. We will be pleased to quote on blueprints and specifications. Interesting and informative literature will be sent on request.

CLOSE TOLERANCES
WITHOUT MACHINING

HIGH TECHNICAL DENSITY

POMET

DUCTILITY OR HARDNESS
COMBINED MATERIALS
WEAR RESISTANCE

POWDER METALLURGY CORPORATION

A SUBSIDIARY OF GENERAL BRONZE CORPORATION

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"HOBART'S
Close Volt-Amp. Control means RIGHT WELDS"

Everywhere that metal is joined Hobart Welders are doing their part in speeding production and lowering costs. Hobart's Multi-Range Dual Control gives you 1,000 combinations of voltage and current . . . Hobart's exclusive Remote Control lets you make adjustments at the work. These and many other features are real time-savers, insure better welds. Ask us for catalog. Prompt deliveries on priority rated orders.

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HOBART—"One of the World's Largest Builders of Arc Welders."

engineering office at 401 North Broad street, Philadelphia. William H. Wadsworth has been chosen to represent the company at 55 West Forty-second street, New York.

♦

Henceforth Continental Roll & Steel Foundry Co. will be known as Continental Foundry & Machine Co., which is more descriptive of the company's facilities. No personnel changes have been made.

♦

According to a recent announcement by Adel Precision Products Corp., Fred T. Miller has been made manager of the customer service department. Mr. Miller has been chief of the company's research and testing laboratories since 1942.

♦

Formerly assistant vice president, C. A. Robinson has been appointed vice president in charge of sales, Acro Electric Co., Cleveland, while Fred R. Lynn has joined the company as vice president in charge of manufacturing.

MEETINGS AND EXPOSITIONS

May 8-10—
American Society of Mechanical Engineers. Oil and gas power division meeting to be held at Mayo hotel, Tulsa, Okla. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

May 11-12—
Society of the Plastics Industry. Annual meeting to be held at Edgewater Beach Hotel, Chicago. W. T. Cruse, 295 Madison avenue, New York 17, is executive vice president.

May 14-16—
American Institute of Chemical Engineers. Semiannual meeting to be held at Hotel Cleveland, Cleveland. S. L. Tyler, 50 East Forty-first street, New York, is executive secretary.

May 17-18—
Society of Automotive Engineers. National diesel fuels and lubricants meeting to be held at Hotel Knickerbocker, Chicago. John A. C. Warner, 29 West Thirty-ninth street, New York, is secretary and general manager.

May 22-24—
American Gear Manufacturers association. Twenty-eighth annual meeting to be held at Westchester Country club, Rye, N. Y. Newbold C. Goin, 301-2 Empire building, Pittsburgh, is manager-secretary.

June 5-7—
Society of Automotive Engineers. National war materiel meeting to be held at Book-Cadillac hotel, Detroit. John A. C. Warner, 29 West Thirty-ninth street, New York, is secretary and general manager.

June 19-22—
American Society of Mechanical Engineers. Semiannual meeting to be held at Hotel William Penn, Pittsburgh. C. E. Davies, 29 West Thirty-ninth street, New York, is secretary.

June 26-30—
American Institute of Electrical Engineers. Summer technical meeting to be held at Jefferson hotel, St. Louis. H. H. Henline, 33 West Thirty-ninth street, New York is national secretary.

June 26-30—
American Society for Testing Materials. Forty-seventh annual meeting to be held at Waldorf-Astoria hotel, New York. Robert J. Painter, 260 South Broad street, Philadelphia 2, is assistant to the secretary.

June 28-29—
Society of Automotive Engineers. National transportation and maintenance meeting to be held at Bellevue-Stratford hotel, Philadelphia. John A. C. Warner, 29 West Thirty-ninth street, New York, is secretary and general manager.

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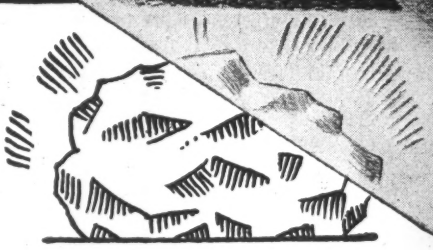

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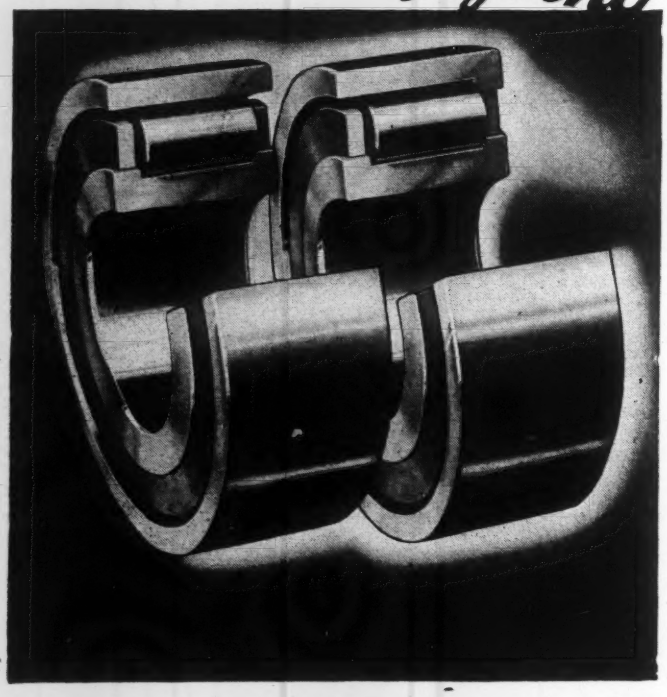

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Choosing the Right Material

(*Continued on Page* 114)

taken—in 1-inch section.

If the completed weld can be tempered, the hard, quenched layer about the weld can be softened and toughened but this often is inconvenient or impossible. However, by preheating the surrounding metal it can be made to have less drastic quenching power and by post heating (keeping the metal warm while it is in process of cooling down), the quench-hardening transformation can be avoided in conformance with the laws of quenching, illustrated in *Fig.* 37. Welding is concerned with avoidance, by one means or another, of hardening under high cooling rates. Welding methods, such as shot welding, that do not automatically heat the adjacent metal are especially touchy and it usually is necessary to give some post-heating treatment to spot-welded steel unless the steel is low in carbon and almost devoid of hardenability.

Weldability of steel depends upon many factors among which are:

1. Cooling rate of the welded joint
2. Hardenability of the steel under the given cooling rate
3. Crack sensitivity of the steel
4. Design of the welded joint.

The safety of the structure depends primarily upon:

1. Presence of physical discontinuities and other internal stress raisers in the welded joint
2. Presence of external stress raisers in the welded joint
3. Internal stress condition of the metal in and adjacent to the welded joint
4. Homogeneity of structure and of properties of the metal in, and adjacent to, the welded joint
5. Type, magnitude and frequency of repetition of imposed stresses.

Hence, testing for weldability is not merely a question of sticking two pieces together by welding and testing the joint in tension or in shear for static strength, but is essentially the problem of determining whether cracks are formed, dangerous stresses introduced, or metallurgical structures created that will crack under repeated loading in service. Fatigue testing of weldments is one means of evaluation, but it is well enough known that presence of cracks or hard structures that are notch sensitive in fatigue precludes the acceptance of welds in or around which either are produced. Locked-up shrinkage stresses will add their quota to the stresses applied in service, and the presence or absence of such stresses needs to be determined, and their importance evaluated.

Some more or less standardized tests are applied to appraise weldability, and the suitability of different welding rods and welding practices. A weld may be bent over a certain radius, the local elongation on the exterior of the bend noted, and the specimens watched for the first appearance of a crack. A weld bead may be laid down on a plate, and the presence or absence of cracking noted. A tee weld may be made, and the weld bent.

The weld and adjacent parent metal may be sectioned and a diamond point hardness traverse made. Hardness limits may be set and "weldability" evaluated on that basis. That excessive hardness really accompanies an un-

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desirable structure may be verified by metallographic examination. The Jominy hardenability test is useful also. Propensity to setting up shrinkage stresses can be evaluated by welding under restraint, and noting whether cracking ensues; or by cutting apart and noting the gap produced as the stress is relieved, when cracking does not occur.

The War Metallurgy Committee has prepared a "Guide to Weldability of Steels", issued March 11, 1943, in mimeographed form, preparatory to more formal publication. This describes some simple methods for directly evaluating weldability as well as by correlation with end-quench hardenability data[12].

Several appraisals have been made of the weldability of N.E. and other alloy steels as compared with the S.A.E. steels they replace which indicate that, at equal hardenability, they behave similarly. Some observers credit the N.E. steels as a class with a better uniformity of results in welding.

Characteristics Affecting Heat-Treating

Appraisal of the quench temperature required and of resistance to tempering of a suggested substitute steel is in order to tell whether former quenching and tempering practice can be applied unchanged. If the steel previously used has been high in nickel or molybdenum, the quenching temperature or the drawing temperature and time would have to be altered.

Under present conditions neither high nickel nor high molybdenum will be used when the necessary hardenability can be secured with less lavish use of these elements through replacement of some of the nickel or molybdenum by small amounts of other elements; hence, whatever available S.A.E., N.E., or new compositions be utilized, their quenching and tempering temperature will fall within relatively small ranges. Once the heat-treating practice is adjusted to suit any of the available steels, it is unlikely that it will fail to suit a substitute steel of equivalent hardenability.

When heat-treatable steel is hardened in quenching it expands in volume, and on tempering it decreases in volume. In blanking dies and the like it is advantageous to have a composition that, at the degree of tempering that gives proper hardness, comes back closely to the dimensions to which it was machined before hardening so as to minimize final grinding. This imposes a double-barreled requirement not present in most uses.

An analogous case is in gears and ball bearing races where the final dimensions and contour are all-important, and for production reasons the amount of stock to be removed by final grinding should be very small and constant. The prior dimensional changes are therefore important. It often is stated that the whole tooling-up is so predicated on the dimensional changes of a particular alloy steel that the substitution of a different steel is impractical once the equipment for handling that particular steel is installed, even though, by starting from scratch,

[12] See also Doan, G. E., J. H. Frye, R. D. Stout, and S. S. Tor—"Evaluation of Weldability by Direct Tests". Office of Scientific Research and Development, War Metallurgy Division. Serial No. M-64, April 30, 1943. 39 pages. Also Kinzel, A. B.—"A Quick Method of Comparing Weldability of Substitute Steels", *Welding Journal*, June, 1942, Pages 2865-2875.

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another steel and another set of equipment would produce just as good a gear or bearing.

In spite of this, Widrig reports[13] successful replacement of carburized gears of a S.A.E. steel containing 1.75 nickel, .60 chromium, .25 molybdenum by an N.E. steel containing .50 nickel, .70 chromium, .22 molybdenum. This replacement was predicated first, on hardenability tests, second, on simulated-service, gear-clashing tests on special equipment set up for the purpose so as to bring in the factors of toughness and fatigue resistance. Widrig makes the following statement: "As to shafts and parts of that nature where gear tests are not involved, we have determined that Jominy end-quench hardenability tests are sufficient for the proper selection of steels".

On the whole, the substitution problem among heat-treated alloy steels involves few processing difficulties. The broad substitution problem, however, requires that the matter of alternative processing methods be considered, as well as that of alternative materials.

Processing by Alternative Methods

Specifications often require that steel be made by some particular melting process, or that certain processes be excluded. Old nonferrous specifications required "virgin metal" and barred scrap. Users often specify forgings and will not consider castings for a particular use. These stipulations attempt to accomplish, by indirection, some unstated end. They usually are a product of ignoranace of how to test for the needed properties, though sometimes they result from sheer stupidity.

The production of "aircraft quality", in some steels, in the electric furnace may be easier than in the open hearth, but when a producer finds out how to do it in the open hearth he should be encouraged to use the more economical melting method rather than prevented from doing so.

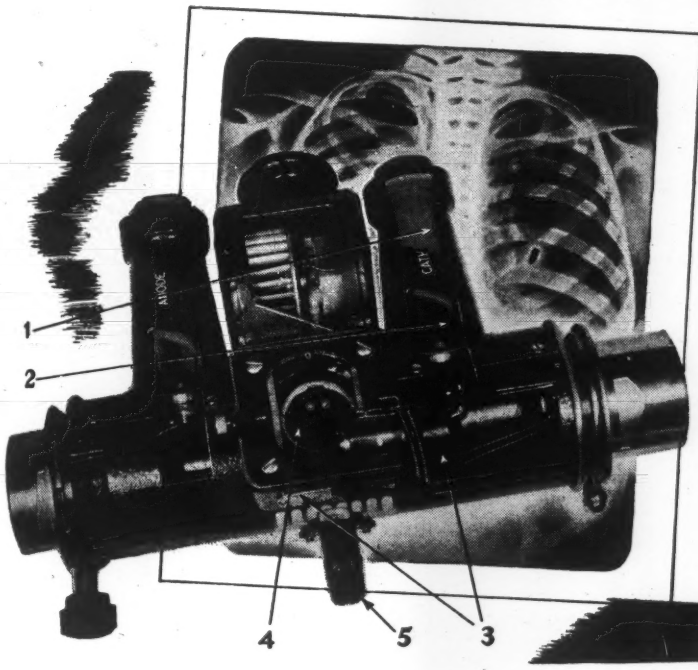
Converter cast steel had a black eye for a long time and was barred by many specifications on the assumption that it was brittle and unsafe—allegations which those conversant with the product knew were unjustified. Knowledge of the effect of grain size and of certain types of sulphide inclusions and the means of controlling both to avoid brittleness grew up in a separate compartment but was not applied by the specification makers, though the metallurgists knew that these means were as applicable to converter steel as to that made by any other process. Instead of specifying toughness and making toughness tests, the specification makers stuck to the old misapprehension. Actual tests proved that the banned converter steel, properly handled, was not lacking in toughness, while the permitted electric or open hearth, improperly handled (in a way not avoided through any provision in the specifications), was lacking. Hence, specifications are being broadened so that converter cast steel is not barred when it is properly made.

The designer's specifications for steel parts which, from the production point of view, could be either wrought or cast material, seldom allow that choice. Many parts have been made from forged blanks for so long a period that

[13] Widrig, S. L.—"N. E. Alloy Steels in Gears", *Steel*, Vol. 112, Jan. 11, 1942, Pages 60-62.

BAKELITE

TRADE-MARK



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2—BAKELITE *Impact-Resistant* Phenolic is employed to reinforce the lower end of the lead-in socket; makes possible a molded thread with high mechanical strength for tube mounting.

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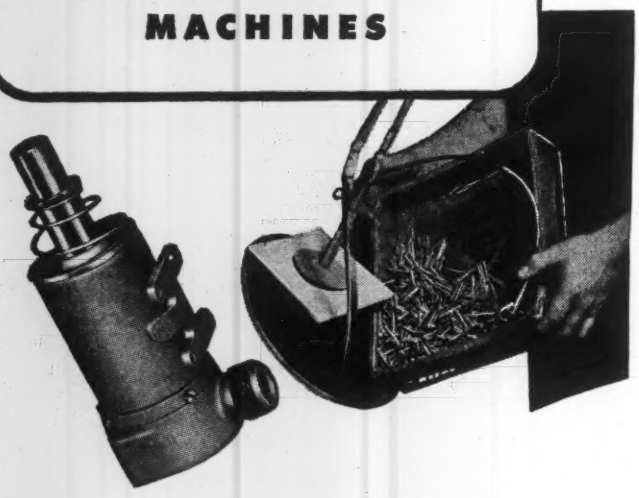

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a shift to castings appears revolutionary.

Somewhere back of a forging is a cropped billet, the cropping of which was intended to remove all pipe and all concealed voids. It is more or less expected that forging closes up small voids, whereas large voids produce an obviously defective forging that is rejected before more work is done upon it.

The inclusions are worked out into plates or stringers, or broken up into "dotted lines" in the forging operation, and this produces directional differences in properties. The "grain direction", revealed by deep etching, is considered especially important in gears and care is taken to work the blank from such directions that the stresses on no tooth of the final gear come at right angles to the grain. In forged and rolled steels, tensile ductility and notched-bar impact figures tend to be lower when the applied force is directed across the grain instead of with it. This is sometimes traceable to the effect of inclusions, sometimes to a nonhomogeneous "banded" structure. In some cases the toughness in the longitudinal direction is entirely normal for the material and heat treatment but the transverse toughness is extremely low, whereas in other lots of same material and treatment it is practically equal to that found with longitudinal specimens. The yield strength is far less likely to show any difference in the two directions.

Cold Forming Accentuates Directional Properties

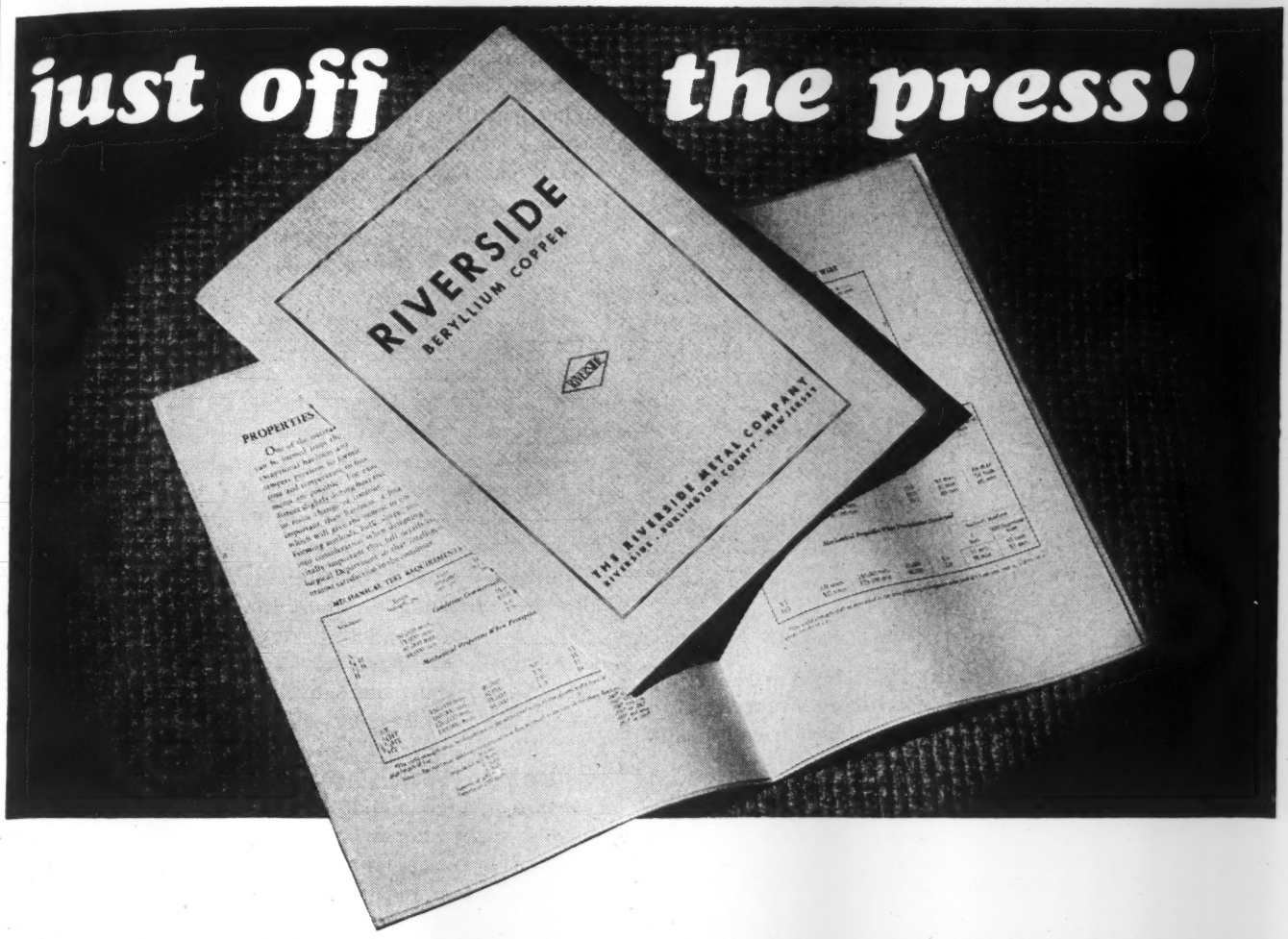
In rolled products where the dimensions are too small to make it easy to take transverse specimens, this condition of low transverse ductility often exists unsuspected by the user and, because it is so rarely that ductility enters into engineering service, the results may be as good as though the steel were free from directional effects. The difference is, however, clearly brought out when severe cold-forming operations are attempted.

Since no hot work is put upon a casting, castings are almost free from directional properties but they are more difficult to heat treat to the optimum properties for that type of material. Forging or rolling breaks up the original large-grained structure produced in the freezing of the steel and existing in the ingot from which the forging has come, and in the casting. It takes longer heating to produce uniformity in the high-temperature structure of the steel when the crystals are large, as in the casting, than when they have been smashed up, as they are in forging or rolling.

However, if homogenization has been adequately carried out, heat-treated castings have, in all directions, a near approach to the properties shown by longitudinal specimens of forged or rolled steels, with much better equality of transverse properties. In a comparison of forged and cast steels, for the particular heats tested, polished specimen endurance limits were higher for the forgings, but the notched endurance limits were higher for the castings.

On the other hand it is difficult to feed a freezing casting of complex shape so as to insure that all of the pipe and shrinkage voids are located in the risers and cropped off, just as the pipe is cropped from the ingot for forging or rolling. The center of a casting therefore may be less

just off the press!



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dense and more spongy than that of a forging. This is avoided in the centrifugal casting of cylindrical objects, where the shrinkage voids are concentrated in the interior so that when the interior is cleaned up by machining the casting is effectively cropped.

Sand castings are more likely to contain blowholes from entrapped gases, introduced in one way or another, than is an ingot. The more complex the casting and the more devious the path the gases have to travel through the freezing metal, the less likely their opportunity for escaping. However, by cutting up sample castings to find out whether blowholes or other types of porosity regularly exist at definite locations, gating and feeding can almost invariably be adjusted to prevent the trouble. Radiographic examination will tell whether large blowholes or voids exist in castings, and routine X-ray or gamma ray examination is often prescribed for castings for severe service. Blowholes or porosity in a lightly stressed portion of the casting may be of no engineering moment, in which case it may suffice to gate the casting so that the holes are "chased" into a harmless location.

That it is not necessary to forge or roll to produce steel parts capable of severe service is evident from the fact that large guns are alternatively produced, from steels of suitable hardenability, by forging or by centrifugal casting. Either one, after heat treatment, withstands the cold-stretching process of "autofrettage", proof-firing with increased charges, and service. In fact, the greater equality of directional properties in the cast gun make it preferred by some authoritites. Hence, there is no inherent objection to steel castings for those services for which forgings normally are used if it is established that the castings are free from voids and have been correctly heat treated.

Castings Reduce Machining Costs

Substitution of a casting for a forging often allows approaching the contour and dimensions of the final part much more closely than is feasible with the forging, with resultant saving in machining costs and in the amount of turnings produced. Turnings are not as acceptable melting stock as heavy scrap, and their use often results in loss of much of the alloying elements they contain. From the points of view of economy and efficiency in production and of conservation of alloying elements, castings often have real advantages.

A notable case is the Ford cast crankshaft replacing forgings and requiring the removal in finishing of only about half the weight that has to be removed from the forged blank.

In steel, a shift from forgings to castings involves no major difference in final properties. When the final properties required are so low that an alloy may be used that is amenable to die casting, still greater savings in machining cost are achieved, since die castings can be produced close to the required finished dimensions. Zinc-base and aluminum-base alloys are being die cast in great quantities and the process is being slowly extended to some types of brasses, though these are more difficult to handle. Nonferrous castings also are being produced to close tolerance in plaster molds. "Precision casting",

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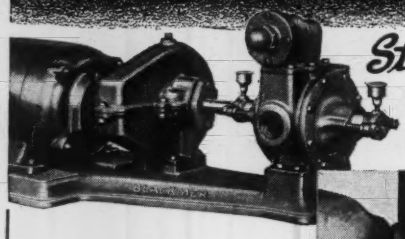
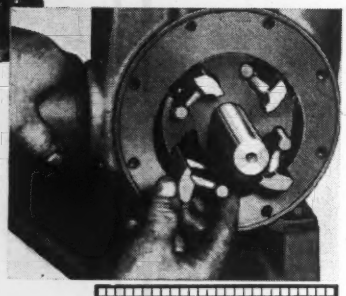
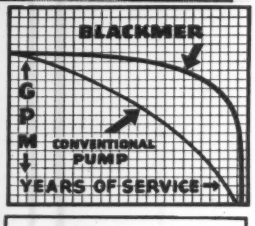


Standardize on BLACKMER ROTARIES

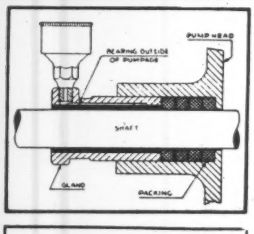


When the "buckets" (swinging vanes) finally wear out, this simple replacement restores a Blackmer pump to normal capacity. It's a 20-minute job.

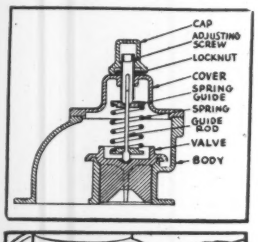
The curve shows the sustained capacity of Blackmer pumps. 20 years of service is not unusual. Compare this with a conventional type rotary pump.



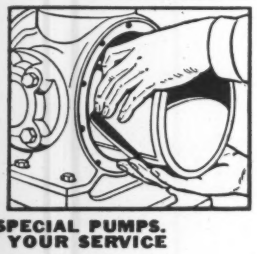
Double bearings eliminate shaft-whip and provide exceptional rigidity. The bearings are located outside the pump casing, away from the pumpage, protected by packing.



Built-in relief valve will by-pass the entire capacity of the pump without shock or end-thrust. This gives positive protection to the pump. Valve operation is quiet—no chatter.



For tough jobs, handling corrosive or mildly abrasive liquids, Blackmer pumps are furnished with removable liners. When finally worn out, the liner is replaced and the pump restored to normal capacity.



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Write for new Bulletin No. 304—Facts about Rotary Pumps.

BLACKMER PUMP COMPANY, 1975 Century Ave., Grand Rapids 9, Mich.

BLACKMER Rotary PUMPS
"BUCKET DESIGN"—SELF-ADJUSTING FOR WEAR

along lines long taken advantage of in the dental industry, is being applied, even to some very high-melting alloys. A typical application is illustrated in *Fig.* 38.

In cases where the required properties can be met, and especially where there is an engineering advantage in using an intentionally porous product (as in bearings that can be impregnated with oil), objects pressed and processed from metal powders according to the methods of "powder metallurgy" offer like opportunities of avoiding or minimizing machining. Powder metallurgy so far is, unfortunately, easily applicable only to rather small parts, though progress is being made in extending the size range as well as in the production of pieces almost free from porosity.

Small gears, formerly cast iron or machined brass or bronze may be die-cast zinc-base alloys, plaster-mold cast brass or sintered powder iron, requiring almost no machining and being adequate for the light service intended. Blind adherence to a given method of production and rigid specifications that bar the use of any other are more readily obviated when the design engineer considers his choice of material in the light of adequacy for a particular service rather than identity with former practice.

(*Concluded in next issue*)

Strain-Rosette Analysis

(*Continued from Page* 96)

paring Equations 7 and 8, one finds immediately the following relations between these two Mohr's circles:

1. They are concentric, the abscissa of the center being A in both cases
2. The radius of the Mohr's circle obtained from the apparent strains is $(1-k)/(1+k)$ times the radius of the Mohr's circle constructed from the true strains
3. The orientation of the gage axis with respect to the principal strains is the same in both cases.

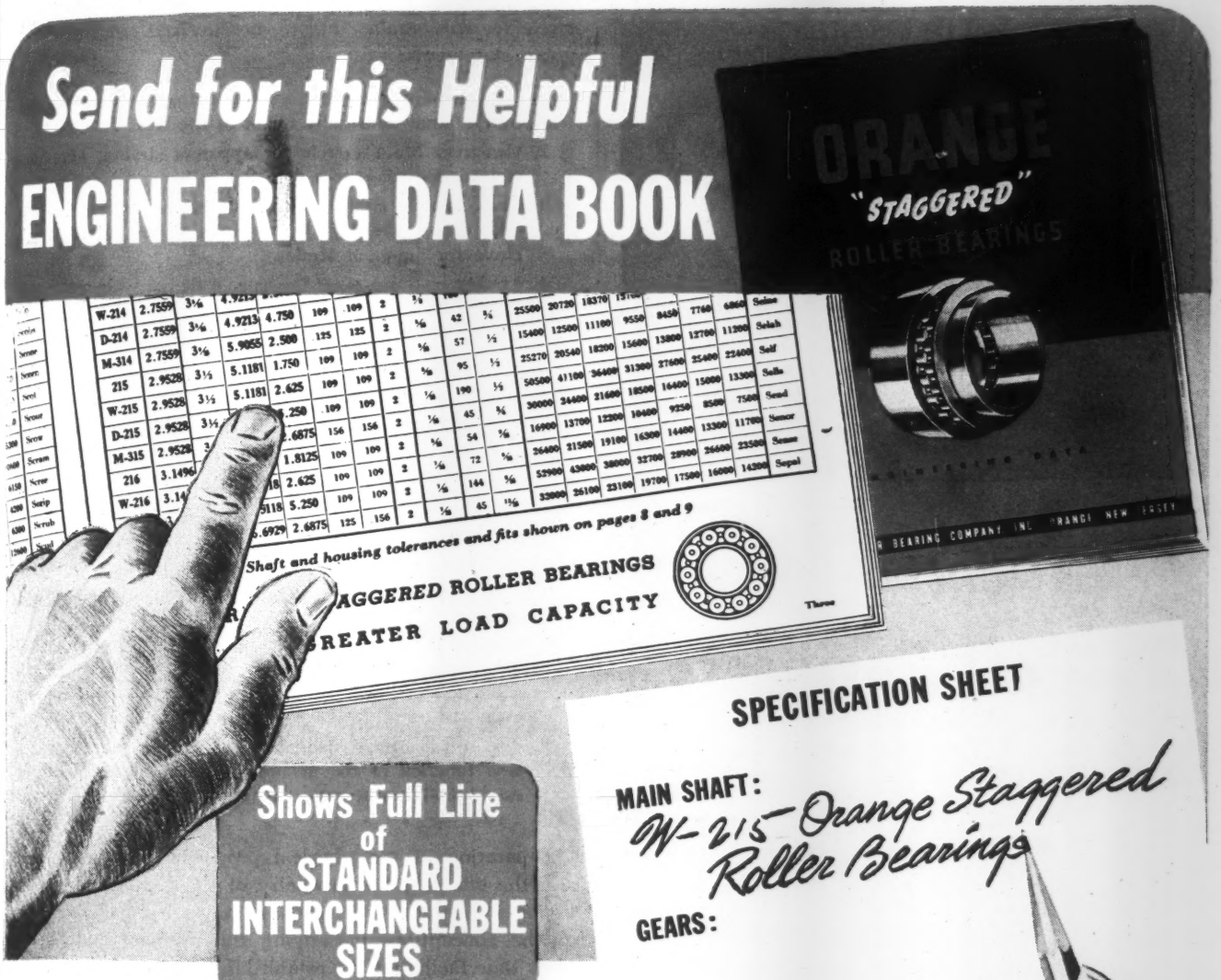
The following simple rules for constructing Mohr's

Nomenclature

α = Angle between gage axis and direction of ϵ_{max}
ϵ_{max} = Algebraically greater principal strain
ϵ_{min} = Algebraically smaller principal strain
ϵ_a = Strain in the direction of the gage axis
ϵ_n = Strain in the direction normal to the gage axis
ϵ_s = Strain indicated by a gage made up of a single straight filament, i. e., true strain
ϵ_c = Strain indicated by a compound-wire gage (made up of loops or V's), i. e., apparent strain
A = $\frac{1}{2}(\epsilon_{max}+\epsilon_{min})$ = abscissa of center of Mohr's strain circles
B = $\frac{1}{2}(\epsilon_{max}-\epsilon_{min})$ = radius of Mohr's circle for true strains
B_c = Radius of Mohr's circle for apparent strains
F = Strain sensitivity factor of filament
F_a = Axial strain sensitivity of compound gage
F_n = Transverse strain sensitivity of compound gage
k = F_n/F_a = specific transverse sensitivity of compound gage
R_s = Reading of gage made up of single straight filament
R_c = Reading of compound gage

NOTE: Dimensions for the symbols are inches per inch for ϵ, A and B; ohms per ohm for R; ohms per ohm ÷ inches per inch for F.

Send for this Helpful ENGINEERING DATA BOOK

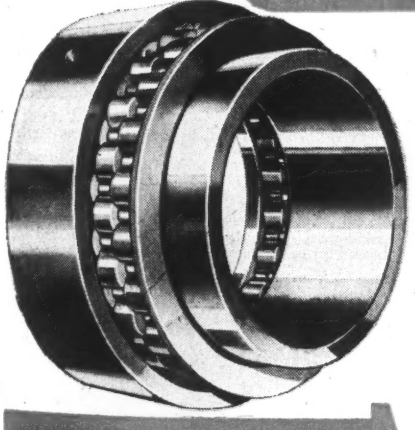


Shows Full Line of STANDARD INTERCHANGEABLE SIZES

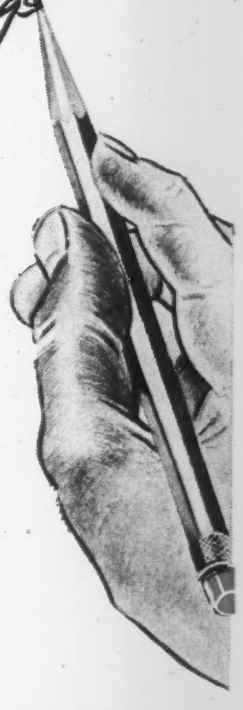
SPECIFICATION SHEET

MAIN SHAFT: *W-215 — Orange Staggered Roller Bearings*

GEARS:



You'll find the answer to heavy duty bearing installations by consulting the Engineering Data Book on Orange Staggered Roller Bearings. This Data Book is built for designing engineers—gives all dimensions, capacities and tolerances in simplified form, set in large, easy-to-read type—shows many typical applications. It explains in detail the exclusive Staggered Roller design, which distributes the load over many small rolls instead of a few large rolls, giving Orange Staggered Roller Bearings greater load-carrying capacity and smoother running than conventional types. Study these advantages before specifying bearings for post-war products.



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